Circular No. 925

Increasing Forage Yields *and* Sheep Production *on* Intermountain Winter Ranges

SELAR S. HUTCHINGS and GEORGE STEWART, *Range Conservationists*
Forest Service

UNITED STATES DEPARTMENT OF AGRICULTURE
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By SELAR S. HUTCHINGS, *range conservationist*, and GEORGE STEWART, formerly *range conservationist, Intermountain Forest and Range Experiment Station, Forest Service*

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INTRODUCTION

The 65 million acres of winter range in the Intermountain region supports only a sparse stand of vegetation, yet it furnishes forage for approximately 4 to 5 million sheep each winter for a period of 4 to 6 months, from November to April. Since the early days of the sheep industry in the West, the drier portions of the region have been used

for winter grazing. These semiarid ranges are well suited for such use because the forage is composed of grasses and low shrubs that grow during the spring and early summer, then dry and cure on the stem before grazing begins. Light snowfalls, usually only 3 to 5 inches deep, furnish water where permanent watering places are few and scattered. This combination of well-cured herbage and easily available snow for water generally provides favorable grazing conditions (fig. 1).

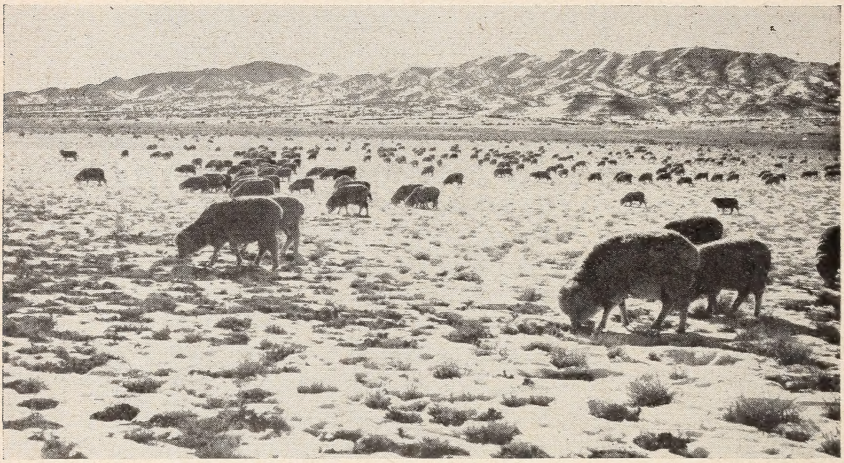

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FIGURE 1.—Sheep grazing winter range in western Utah. The soft snow, 2 to 3 inches deep, and well-exposed plants provide ideal conditions for winter grazing. Vegetation is primarily winterfat and shadscale, with some bud sagebrush.

Winter ranges of the Intermountain region are located in eastern and western Utah, Nevada, southwestern Wyoming, and southern Idaho (fig. 2). Similar ranges extend into adjacent States. These ranges lie in great blocks, often several million acres in size and usually at considerable distances from spring-fall and summer range lands.

In October most of the sheep within the region are trailed 50 to 200 miles from the spring-fall ranges to the winter ranges, returning over the same trails in April and May (*7*).[1] They are moved to the higher mountains for summer grazing and are brought back to the spring-fall ranges at the end of the summer period.

During the early development of the western livestock industry, grazing on the vast areas of winter range was largely a matter of shifting animals to new ranges. As those already in use became crowded, sheep and cattle were moved into new areas more remote from centers of civilization (*1*). More than 50 years ago, however, almost every part of the West suitable for livestock was fully grazed and expansion into new territory became impossible. Numbers of animals continued to increase even after this and as a result, many winter ranges were seriously overgrazed. Excessive use of the grazing resources brought about reduction of vegetation and loss of soil through increased wind and

[1] Italic numbers in parentheses refer to Literature Cited, p. 61.

water erosion. Extremes in weather conditions and prolonged droughts accentuated the seriousness of range depletion. Free use of winter ranges in the Intermountain region ended when they were put under management following passage of the Taylor Grazing Act of 1934.

Today the "frontier" of the livestock industry lies in the application of management practices which will restore and maintain ranges at their maximum production of both forage and livestock. This is particularly true of the winter ranges of the Intermountain region.

The Desert Experimental Range, a unit of the Intermountain Forest and Range Experiment Station, maintained by the Forest Service, was established in 1933 to study the major phases of winter-range manage-

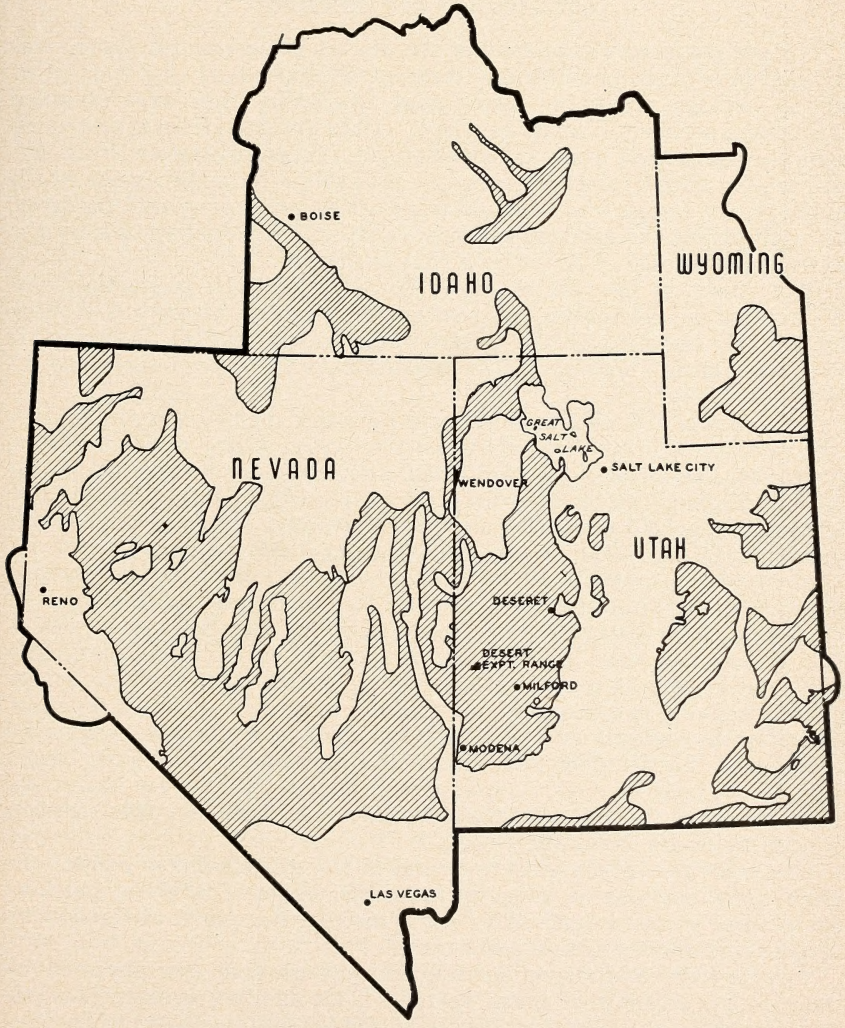

FIGURE 2.—Winter sheep ranges of the Intermountain region.

ment. Fifty-five thousand acres of representative winter range in the salt-desert shrub areas of western Millard County, Utah, were selected and fenced into allotments and experimental pastures. This circular presents the results of studies extending over a 13-year period, 1935–47. The chief objectives of the studies were to determine: (1) The utilization of forage species by sheep; (2) the influence of precipitation on herbage production and plant density; (3) the effects of grazing intensity on forage yields; and (4) the effects of grazing intensity on sheep and wool production. Results from these studies will be generally applicable to the salt-desert shrub areas which comprise approximately 66 percent of the winter ranges in the Intermountain region.

METHODS OF STUDY

For the purposes of the studies the Desert Experimental Range was divided into range pastures and large range allotments (fig. 3). Most of the herbage production and forage utilization data were obtained from the experimental range pastures. Data obtained from the pastures were supplemented with information on forage utilization from the moderately grazed range allotments. An evaluation of the species which make up the forage was obtained from the moderately grazed pastures, by multiplying the average herbage yields of individual species by the average percentage of its herbage that was eaten.

The effect of the precipitation on total herbage production was determined by correlating the yearly precipitation, October 1 to September 30, obtained at the Desert Experimental Range headquarters with the average herbage yields measured the following October on all range pastures.

To evaluate the effects of grazing intensity on herbage yields data were obtained from three sources—the experimental range pastures, moderately and heavily grazed range allotments, and protected enclosures. Herbage yields recorded each year on the lightly, moderately, and heavily grazed range pastures were compared and yield trends were computed for the total herbage as well as for individual species.

Most of the information on effects of grazing intensity on herbage production was obtained from a series of 20 fenced range pastures (fig. 4). Sixteen of these were 320 acres in area and four were 240 acres. Six of the 20 pastures were grazed lightly, six moderately, and six heavily during either one or a combination of two grazing periods of the winter grazing season, as follows: Early, middle, late; early and middle; early and late; and middle and late winter. These periods were arbitrarily established by dividing the winter grazing season into three equal periods of about 50 days. Early winter included the period November 15 to January 3; middle winter, January 4 to February 23; and late winter, February 24 to April 10.

The other two pastures were grazed in the middle winter period, one moderately and one at a heavy intensity similar to that on much of the general winter range. This was somewhat heavier than the grazing in the other heavily grazed pastures.

The desired intensity of grazing in each pasture was obtained by varying the number of sheep grazed. The numbers grazed were adjusted each year to compensate for fluctuations in herbage yield. The sheep placed in each pasture were weighed at the beginning of each

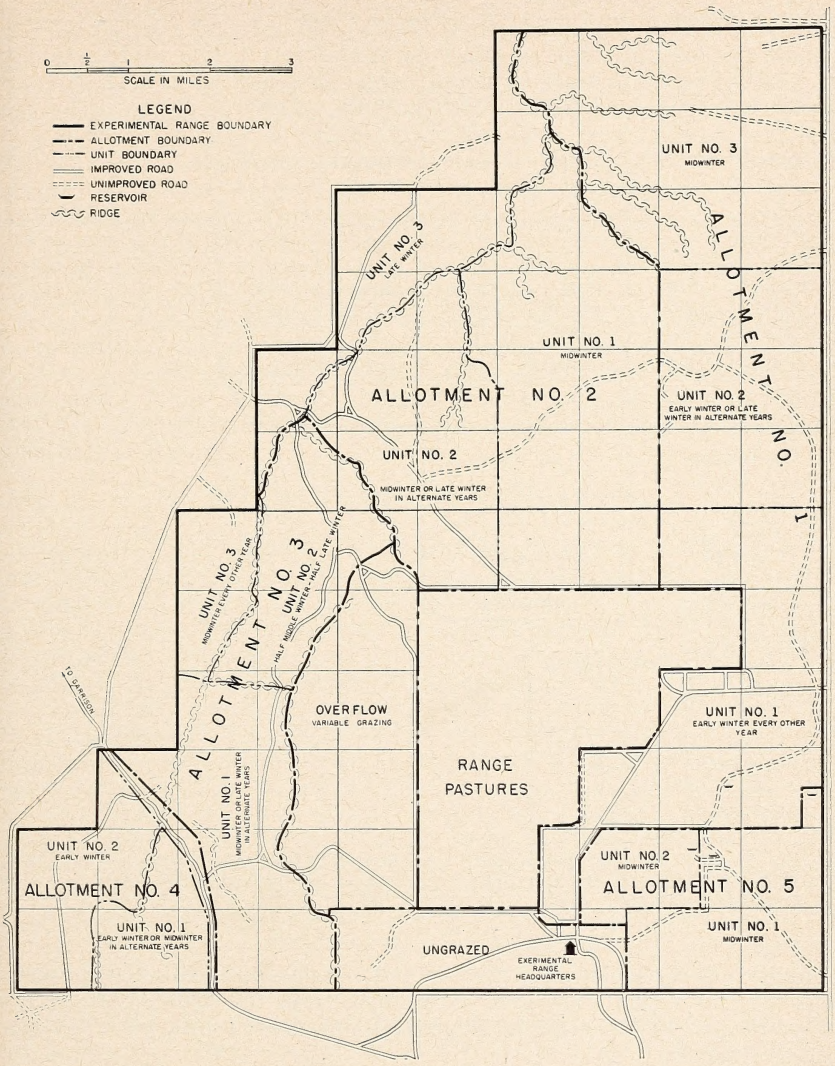

FIGURE 3.—Location of range pastures and allotments at the Desert Experimental Range. All allotments were grazed at moderate intensity.

grazing period and at the end of the winter grazing season. The grazing intensities and the method of stocking the pastures are described in more detail in the section, Influence of Grazing Intensity, page 18.

Data on herbage yields, plant density, and forage utilization were recorded each year. Plant density and herbage production estimates were made on a series of circular 200-square-foot plots established within each pasture—64 in the large pastures and 48 in the small pastures. Plant density, estimated by the square-foot-density method (*20*) in October or early November, was recorded each year from 1935 to 1945 and in 1947. Herbage yields were determined by the weight-estimate

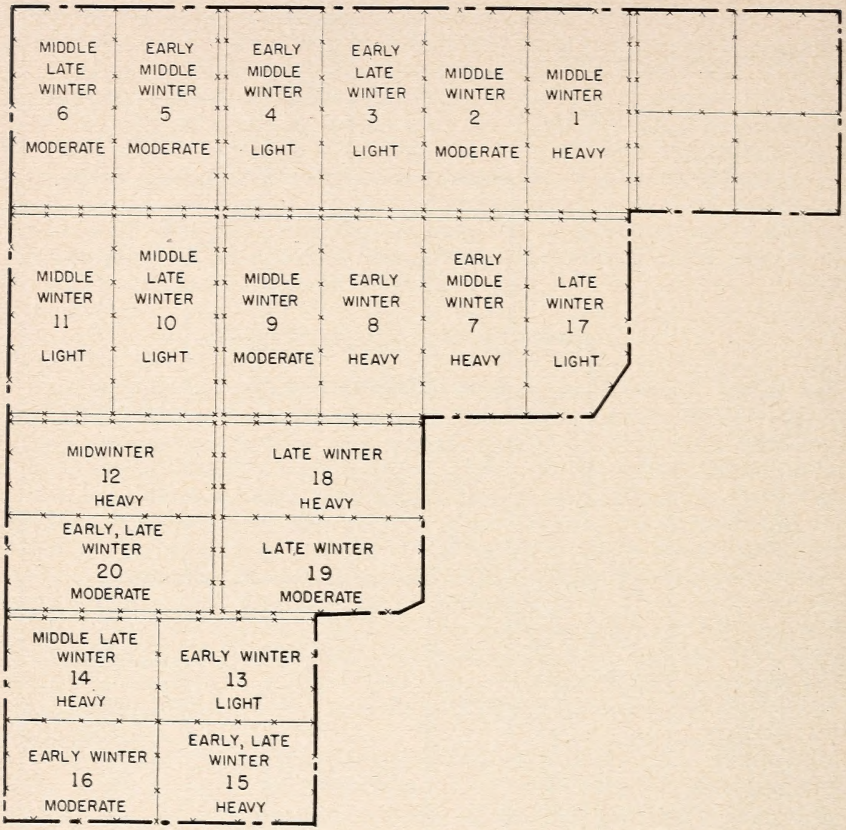

FIGURE 4.—Fenced range pastures at the Desert Experimental Range. Intensities of grazing in the pastures were light, moderate, or heavy during the various grazing periods, as indicated.

method (*12*) for the same period with the exception of the first 3 years, 1935–37, for which they were determined from the density estimates, using the calculated relation (regression) of density and yield for the period 1938–47.

Estimates of herbage utilization were made at the end of grazing periods on the same plots that were used for obtaining plant density and herbage yield. Percentage utilization of individual shrubs and grasses was determined by the ocular-by-plot method described by Pechanec and Pickford (*11*). Percentage utilization of the current herbage of each species was obtained by averaging the estimates made on the plots. The weight of herbage utilized was computed by multiplying the total yield of each species by the average percentage utilization.

Herbage yields obtained at varying periods on the moderately and heavily grazed range and on the protected enclosures and heavily grazed range were compared and used to supplement information obtained in the experimental range pastures.

To compare the effects of moderate and heavy grazing on sheep and wool production two typical winter range allotments were selected and grazed by full winter bands of 2,500 to 3,000 sheep.[2] In 1935 both allotments were similar with respect to topography, vegetation, and range condition. One allotment was fenced, divided into units, and moderately grazed. The other allotment was heavily grazed. The two herds selected were essentially similar with respect to breeding history as well as summer and winter range operations. Sheep in both herds were range-bred Rambouillets of good quality.

The two herds were alternated from year to year between the two range allotments. This was done to eliminate as far as possible the effects of any difference between the two herds.

Data obtained each year in wool yields, lamb crops, death losses, sheep weights, and income were used to evaluate the effects of moderate and heavy grazing intensity on sheep production. Management practices used for the two herds differed as well as intensity of grazing. These are explained in detail in the section, Sheep Production on Range Allotments, page 44.

WINTER RANGE VEGETATION

Vegetation used for winter grazing grows mainly on the broad semiarid valley lands, and on the low-lying hills and foothills within the Intermountain region. The characteristic mixture of grasses and low shrubs is sparse, and there are open spaces between the plants. As estimated by the square-foot-density method, plant density varies usually between 2 and 8 percent of the ground surface.

Four major plant formations are found on the winter ranges of the Intermountain region. The salt-desert shrub formation (fig. 5, *A*) covers about 43 million acres, sagebrush-grass (fig. 5, *B*) 13 million acres, pinyon-juniper woodland (fig. 5, *C*) about 8 million acres, and the southern-desert shrub about 1 million acres. These plant formations are referred to as major range types in "The Western Range" (*21*) and the Agriculture Yearbook for 1948 (*15*).

Vegetation on the Desert Experimental Range is representative of the salt-desert shrub formation, which covers 66 percent of the entire winter range. This formation includes a large number of plant associations or types which are usually composed of a mixture of shrubs and grasses dominated by one or two species. These types are normally quite distinct, but sometimes they merge imperceptibly into one another (fig. 6). Many occupy large parts of a single valley and their aggregate over the winter range may be several million acres. The various types show preference for soil with certain characteristics with regard to soil salts or to surface drainage, similar to those described in Tooele, Escalante, Pine, and Wah Wah Valleys in Utah (*9*, *17*, *19*).

Shadscale is the most extensive plant on the general winter range. It forms large almost pure stands on the deep, well-drained soils in the valley bottoms. On the higher valley slopes and low hills,

[2] Special appreciation is expressed to George C., Elray, Edwin, Alvin L., and William D. Jackson, owners of the experimental herds, for their wholehearted cooperation in the experimental grazing studies. Appreciation is also expressed to John Bayless, Jess Guymon, Clarence Ingram, Walter James (deceased), Junius Metcalf, and Harry Sperry; and to the Fountain Green Wool Growers and Fairview Cooperative Sheepmen, who at various times participated in the experiments.

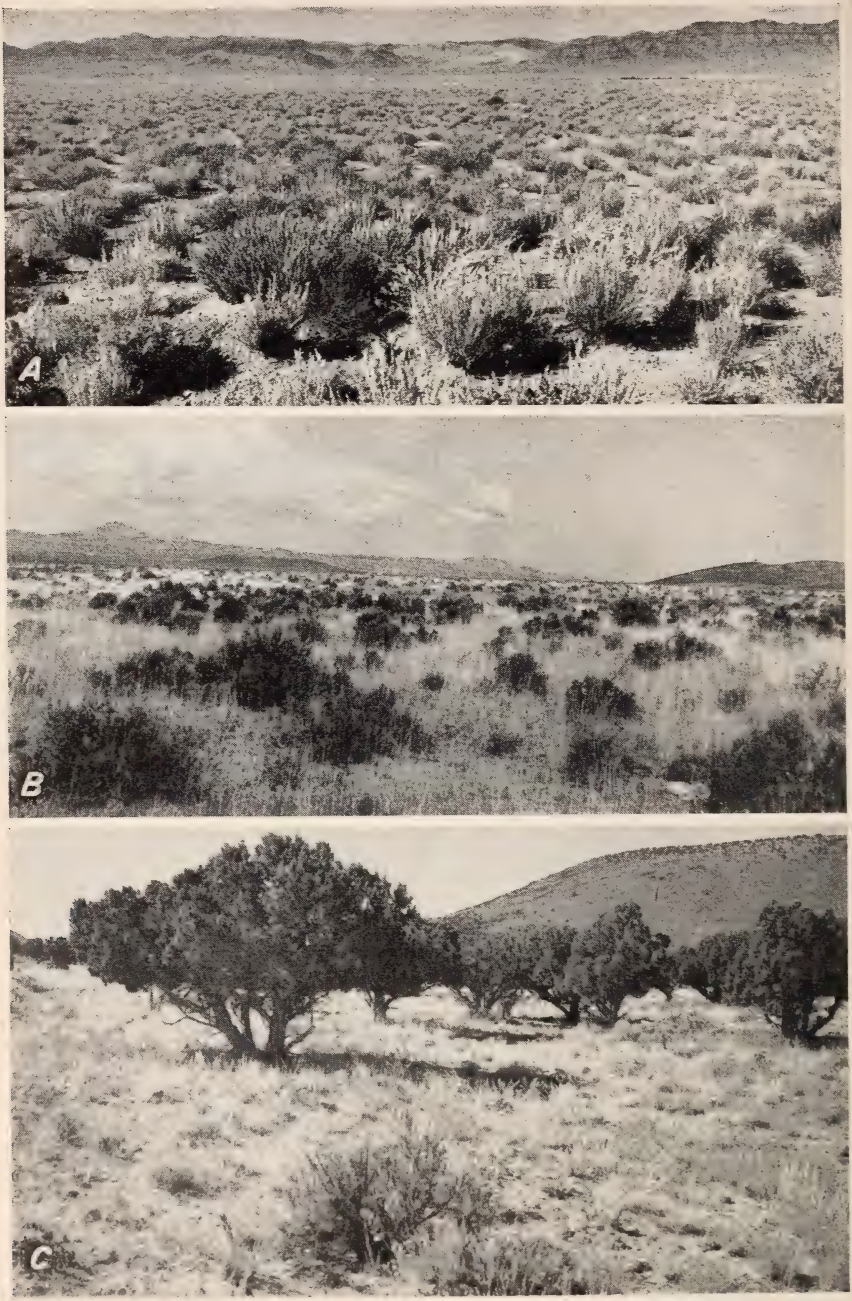

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FIGURE 5.—*A*, Typical shadscale-winterfat-grass subtype of the salt-desert shrub formation; *B*, sagebrush-grass formation containing big sagebrush and galleta; *C*, pinyon-juniper woodland formation with an understory of big sagebrush, winterfat, and Indian ricegrass.

shadscale is mixed with grasses and other shrubs. Wherever grazing has been excessive, on mixed shadscale-winterfat-grass ranges, the palatable grasses and winterfat ("whitesage") have often been supplanted by shadscale, which is protected from excessive grazing by sharp thorns.

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FIGURE 6.—Small rabbitbrush type (left) merging into winterfat type (right). Plant types are usually dominated by one or two plants, and lines of demarcation between them are often distinct.

Two subtypes containing shadscale cover almost half of the Desert Experimental Range. The shadscale-grass subtype occupies 14,276 acres and the shadscale-winterfat-grass is found on 12,687 acres (fig. 7). When the grass within the subtype is primarily a single species, it is listed in the subtype designation. For example, where Indian ricegrass is a major species, the shadscale-grass subtype is often called the shadscale-Indian ricegrass subtype. Shadscale in pure stands occupies areas on the experimental range too small to map, although it is extensive on the general winter range.

The type dominated by winterfat is probably the second most extensive found on the winter range. Subtypes of almost pure winterfat exist on the deep, fine, alluvial soils near the valley bottoms and in the broad, fairly level drainages where runoff from summer storms accumulates. On the higher valley slopes, winterfat grows in mixture with other species. These mixed subtypes furnish excellent forage for sheep, especially if the associated species include Indian ricegrass or black sagebrush. The winterfat type is represented on the experimental range by two subtypes: Winterfat-small rabbitbrush-grass, 5,132 acres; and pure winterfat, 3,949 acres.

Plant types dominated by mat and Gardner saltbushes are not widely distributed within the Intermountain region; but on localized areas in eastern Utah and southwestern Wyoming they are extensive enough to be important. They are usually found in almost pure stands on the lower valley slopes and level soils of the valley bottoms, which occasionally receive runoff from melting snows or summer storms. Types containing these saltbushes furnish excellent winter forage for sheep.

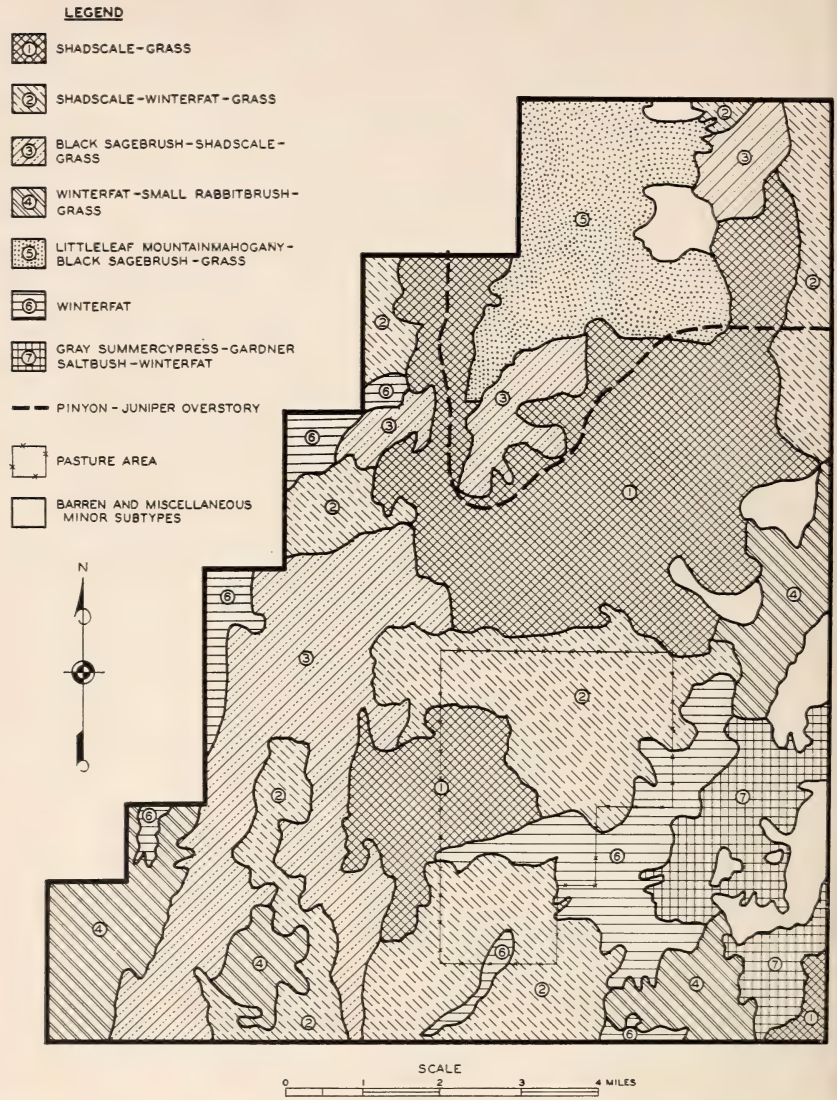

FIGURE 7.—Plant subtypes of the Desert Experimental Range as mapped and classified in 1934.

Gardner saltbush occurs on the Desert Experimental Range in one small subtype (2,835 acres), where it grows mixed with gray summercypress and winterfat.

Plant types dominated by black greasewood, saltgrasses, pickleweed, small rabbitbrush, other rabbitbrushes, or miscellaneous species cover approximately 3 million acres on the general winter range. Two or three of these occur on the experimental range but they are too small to be indicated on the map. Black greasewood forms a narrow fringe around the bare playa in the bottom of the valley. Small rabbitbrush

grows in almost pure stands on a few small sandy areas but for the most part it occurs as a component in subtypes with winterfat, black sagebrush, and shadscale. Other rabbitbrushes grow in sparse stands along one or two of the larger drainage channels.

The sagebrush-grass formation covers approximately 13 million acres or 20 percent of the winter range within the region. This plant formation consists largely of two plant associations or types, the big sagebrush-grass, which occupies almost 10 million acres, and black sagebrush, which covers about 3 million acres. The largest areas covered by the big sagebrush type are found on deep alluvial soils along the foothills and in the valleys of high elevation where annual precipitation is 10 to 15 inches, and the soil is well-drained and free from soil salts. On the foothills the big sagebrush type often forms an understory with pinyon-juniper, both often extending down the drainage channels into the black sagebrush, winterfat, and shadscale types. It is also often found mixed with shadscale or greasewood near the valley bottoms (*9*, *16*, *17*). Most of the big sagebrush type is spring-fall range and only the low-lying, more arid portions of the type are used for winter grazing. While big sagebrush itself is only moderately palatable under normal winter conditions, it is often heavily grazed during periods of deep snow. The associated species in the big sagebrush type on winter range furnish considerable forage, especially when they include desirable and palatable species like galleta, winterfat, or squirreltail. Although the big sagebrush type covers large areas on the winter range in the Intermountain region, it occurs only as scattered plants along one or two of the drainages within the experimental area.

The black sagebrush type is one of the most productive and desirable on the winter range. This type grows on the rocky soils of the higher valley lands and foothills where soil is well-drained and soil salts are not excessive. Soils are usually much shallower than those where big sagebrush grows because a caliche layer (crust of calcium carbonate) is commonly formed 18 to 24 inches below the surface. Intermingled species include Indian ricegrass, Salina wildrye, needle-and-thread, galleta, bud sagebrush, and small rabbitbrush. Pinyon-juniper and littleleaf mountain-mahogany sometimes form an overstory, either in patches or open stands.

The black sagebrush type provides choice grazing for sheep. Besides being productive, black sagebrush and most of the associated species are highly palatable. Only two black sagebrush subtypes are found on the experimental range. One, the black sagebrush-shadscale-grass subtype, which covers 8,981 acres, is probably one of the most productive on the experimental range. In the other, black sagebrush and grass occur as an understory within the scattered littleleaf mountain-mahogany on 4,542 acres. In addition to these two subtypes, black sagebrush is found on some areas mixed with winterfat and small rabbitbrush.

The pinyon-juniper woodland formation extends over about 8 million acres (12 percent) of the winter range. Most of the pinyon-juniper grows in open stands, usually with big sagebrush and black sagebrush in the understory. Dense stands of pinyon-juniper with little herbaceous or shrubby understory are found on considerable areas of the winter range. On the experimental range Utah juniper and singleleaf pinyon form an open, scattered overstory on 10,560 acres. The range

covered with pinyon and juniper has been classified on the basis of the vegetation found growing in the understory.

Some vegetation of the southern-desert shrub formation, characterized by shrubs of low grazing value such as creosotebush, yucca, and mesquite, occurs in southwestern Utah and southern Nevada (*24*). Only about 1 million acres of this area is used for winter grazing because of scanty rainfall and consequent low, undependable forage production. This plant formation does not occur on the experimental range.

At least four introduced annuals—Russian-thistle, cheatgrass and foxtail bromes, and halogeton—have invaded large areas of the winter range. Although these plants are not considered in this circular as forming subtypes, they have considerable effect on grazing, since they have supplanted the better native forage species on many winter ranges. They therefore need careful consideration in any program designed to improve winter ranges.

Russian-thistle, the oldest of these invaders, grows profusely in depleted winterfat and big sagebrush subtypes whenever summer precipitation is ample. Cheatgrass and foxtail bromes have taken over large parts of depleted shadscale and black sagebrush subtypes, in some places making up more than half the vegetation. It is also prevalent in the big sagebrush types where other grasses have been destroyed. Halogeton, the most recent intruder, has spread over much winter range land in Nevada, Idaho, and Utah, being well adapted to saline soils. It grows mainly on overgrazed and depleted ranges, and along road shoulders or on other land that has been disturbed, such as abandoned dry-farms or trampled areas. If eaten in quantity, this plant is poisonous to sheep. Two of these species, Russian-thistle and cheatgrass brome, occur on the experimental range in minor quantities

FORAGE UTILIZATION

Although several hundred plant species are found on the winter range, only 30 are abundant and palatable enough to be classed as important for forage. The importance of a plant as forage is determined largely by two factors—its relative abundance and the degree to which it is utilized. These two factors are not independent of each other, and must be considered together in assessing the importance of the different species.

Most of the grazing on winter ranges, especially during the early midwinter period, occurs while the plants are dormant. The grasses are cured and dry except for a few basal leaves and stems which often remain alive and green during part of the winter. Most of the shrubs are completely dormant, although the twigs and stems on a few species appear to remain alive and somewhat succulent in most years. The forage therefore consists largely of mature, dry herbage. In the late winter period, in years when plant growth starts early, the sheep relish the new green vegetation, especially that of bud sagebrush and grasses.

Utilization of Individual Species

Ratings of relative abundance within the naturally sparse stands of vegetation on winter ranges, and utilization data obtained on all mod-

erately grazed areas at the Desert Experimental Range, including both range allotments and pastures, serve to illustrate how these factors are related in determining the importance of various species as forage (table 1).

Only a few of the plants whose herbage is utilized at 45 percent or more are relatively abundant and occur widely over the winter range. These include winterfat, Indian ricegrass, galleta, and globemallow. Other species such as hopsage, black sagebrush, bud sagebrush, fourwing saltbush, squirreltail, sacaton, Salina wildrye, and Mormon needlegrass, whose herbage is utilized 45 percent or more, generally occur in limited subtypes or comprise only moderate or minor amounts of vegetation. With the exception of shadscale, species utilized below this level occur in only one or two localized plant subtypes or form only

TABLE 1.—*Relative abundance and average utilization of herbage by sheep of principal forage plants on moderately grazed pastures and allotments at the Desert Experimental Range, 1936–46*

Species	Relative abundance [1]	Average utilization of herbage
Shrubs:		*Percent*
Hopsage, spiny	1	80
Sagebrush, black	2	70
Winterfat, common	5	60
Sagebrush, bud	3	50
Saltbush, fourwing	1	50
Sagebrush, fringed	1	40
Summer-cypress, gray	1	35
Saltbush, Gardner	1	30
Saltbush, shadscale	5	25
Mountain-mahogany, littleleaf	1	25
Ephedra, Nevada	2	20
Snakeweed, broom	2	15
Rabbitbrush, small	3	10
Rabbitbrush, rubber	1	10
Grasses:		
Squirreltail, bottlebrush	3	75
Sacaton, alkali	3	75
Ricegrass, Indian	4	75
Wildrye, Salina	2	45
Galleta	5	45
Needlegrass, Mormon	1	45
Wheatgrass, bearded bluebunch	2	30
Dropseed, sand	3	25
Dropseed, spike	1	20
Grama, blue	1	20
Forbs:		
Globemallow, gooseberryleaf	4	80
Pepperweed	1	25
Russian-thistle, tumbling	3	10

[1] Based on a scale from 1 to 5: 1, occurring infrequently in minor subtypes; 2, well-distributed in minor subtypes or infrequent in major subtypes; 3, present in moderate numbers in major subtypes; 4, well-distributed in one or more major subtypes; 5, dominating one or more major subtypes.

a small part of the plant cover. Many other plant species in addition to those listed furnish some forage, but the contribution of each is extremely small except in a few areas.

Blue grama, a desirable and highly palatable forage species in the Southwest and Plains regions, is utilized only very lightly on the Intermountain winter sheep ranges. Average use of the herbage of this species was only 20 percent.

Bearded bluebunch wheatgrass, considered to be one of the major forage species on the spring-fall ranges of Utah and Idaho, is found on only a few of the foothill areas of the winter ranges, and is utilized only about 30 percent.

Bottlebrush squirreltail, a species generally considered to have low palatability on spring-fall and summer ranges, is one of the most palatable of all winter forage species. The basal leaves of this plant begin to grow in the late fall and they remain green and succulent during the winter. Sheep relish this green foliage. Only scattered plants of squirreltail occur on the heavily grazed winter ranges. However, under moderate grazing or protection, this species increases in abundance on the foothill areas.

More exact information on the relative importance of several plants as forage was obtained within the seven moderately grazed range pastures during the period 1935–45 (table 2). Of the forage used during this period, shrubs made up 59 percent, grasses 36 percent, and forbs 5 percent. Seven species contributed almost 95 percent of the total forage. Five of these—winterfat, shadscale, Indian ricegrass, galleta, and sand dropseed—produced 80 percent of the herbage and furnished 88 percent of the forage.

Differences between the proportion of total herbage produced and that utilized as forage are due primarily to differences in palatability, although several other factors such as growth habits of plants also influence the degree of utilization. As table 2 shows, the more palatable species—winterfat, Indian ricegrass, galleta, bud sagebrush, and globemallow—contributed a higher proportion of the forage than of the total herbage. The species of lower palatability—shadscale and sand dropseed—provided a lower proportion of forage than of herbage.

Periodic Trends in Utilization

When sheep first begin to graze a winter range they select primarily the choicest portions of the more palatable forage species such as the seed stalks of black sagebrush and Indian ricegrass. At later intervals as the choicer forage is consumed, more of the moderately palatable forage is eaten. Toward the end of a winter grazing period, sheep subsist mainly on the less palatable species.

This pattern of utilization is typical of both the early and midwinter grazing periods when the vegetation is cured and dry, and little if any new growth is available to the sheep. Table 3 shows the percentage utilization of several forage plants during a 40-day midwinter period on a typical moderately grazed range allotment. During the first 10 days, sheep ate 45 percent of the globemallow, 40 percent of the black sagebrush, and 35 percent of the Indian ricegrass herbage, and only small amounts of bud sagebrush, winterfat, galleta, and shadscale. During the second 10-day interval, rather heavy use of globemallow, black sagebrush, and Indian ricegrass continued, but during the third interval

grazing of these highly palatable species dropped sharply because little of the choice herbage remained to be eaten. At this time, utilization of bud sagebrush increased noticeably and that of winterfat and shadscale slightly. In the fourth interval, grazing of the highly palatable species continued low, that of bud sagebrush dropped, and consumption of winterfat, galleta, and sand dropseed increased. At the end of the 40-day period the study area was considered to be about properly grazed although the globemallow and black sagebrush probably received more than a desirable degree of use.

TABLE 2.—*Average herbage production, percent utilization of herbage by sheep, and forage furnished on seven moderately grazed range pastures at the Desert Experimental Range, 1935–45*

Species	Herbage production		Herbage utilization	Forage furnished	
	Quantity	Percent of total		Quantity	Percent of total
Shrubs:	*Lb./acre*	*Percent*	*Percent*	*Lb./acre*	*Percent*
Winterfat	47.7	22.4	54.0	25.8	35.1
Bud sagebrush	3.4	1.6	52.1	1.7	2.3
Shadscale	60.6	28.4	21.3	12.9	17.6
Other	23.7	11.1	12.2	2.9	3.9
All shrubs	135.4	63.5	32.0	43.3	58.9
Grasses:					
Indian ricegrass	14.2	6.7	73.3	10.4	14.1
Galleta	20.0	9.4	46.9	9.4	12.8
Sand dropseed	27.7	13.0	22.8	6.3	8.6
Other	4.8	2.2	6.8	.3	.4
All grasses	66.7	31.3	39.6	26.4	35.9
Forbs:					
Globemallow	4.3	2.0	74.1	3.2	4.4
Other	6.8	3.2	9.2	.6	.8
All forbs	11.1	5.2	34.3	3.8	5.2
Total	213.2	100	34.4	73.5	100

In years when precipitation was favorable and winterfat made rank woody growth and produced good seed crops, utilization was lower than in years when it did not fully mature. In each of the winters 1935–36, 1937–38, and 1938–39, when winterfat had made excellent growth, utilization of its herbage and tender twigs was only about 45 percent. The average utilization was about 65 percent in years when it did not mature.

Repeated observations on the moderately grazed ranges revealed that the shorter growth of winterfat, on the gravelly soils of the foothills and valley slopes was utilized more heavily than the more thrifty, coarser growth found on the finer soils in the drainages and valley bottoms.

TABLE 3.—*Percentage utilization of total herbage production of forage plants on a moderately grazed range allotment during 10-day intervals in a 40-day grazing period of a rather typical winter*

Species	Jan. 5–14	Jan. 15–24	Jan. 25–Feb. 3	Feb. 4–13	Total
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Globemallow	45	30	5	5	85
Black sagebrush	40	30	10	0	80
Indian ricegrass	35	30	5	5	75
Bud sagebrush	5	10	40	15	70
Winterfat	10	10	15	25	60
Galleta	10	10	5	30	55
Sand dropseed	0	5	5	15	25
Shadscale	5	5	10	5	25

Frequently sheep ate only the central portions of galleta tufts, leaving the coarser growth around the edges. They also ate some individual patches but left adjacent ones untouched.

Sheep definitely preferred the tops of Indian ricegrass and the seedstalks and foliage of small plants to the herbage produced by large plants. Utilization of this species was also heavier in years when late summer rains stimulated the growth of the basal leaves and freshened up the herbage.

During short periods throughout the winter when melting snow softened the otherwise dry vegetation, sheep often ate galleta, sand dropseed, blue grama, and Russian-thistle in preference to other normally more palatable species.

In some years many forage species such as spiny hopsage, bud sagebrush, squirreltail, Indian ricegrass, and Salina wildrye began to grow in March and April, during the late winter grazing period. Sheep relished this green succulent growth and ate it in preference to herbage of other species which was still dry and dormant, thus altering the utilization pattern during this period.

Influence of Relative Production of the Species

In general the percentage utilization of the herbage varied with the amount and relative production of the different species. The grazing of a given species tended to increase with a decrease in its relative production (table 4).

Data from moderately grazed range pastures show this inverse relation. In pasture 6, where winterfat production averaged 4 pounds per acre and made up only 2 percent of the total herbage, 77 percent of the herbage was utilized. In pasture 16 with 118 pounds of winterfat herbage, 51 percent of the total yield, average utilization was only 48 percent.

Utilization of several other species also followed the same general pattern. Grazing of Indian ricegrass, galleta, and sand dropseed was greater on range pastures where yields were small and less on those where yields were high. This relation was less pronounced for galleta, which was fairly evenly distributed on the range.

The weighted utilization of the three grasses taken together was also affected by the relative amount of total grass herbage available. In fact, the inverse relation of utilization to production was closer than that for any of the individual grass species.

TABLE 4.—*Average herbage yield, proportion of total, and herbage utilization of four major forage species in moderately grazed range pastures, 1938–45*

Species and pasture number	Herbage yield	Proportion of total yield	Herbage utilization
Winterfat:	*Pounds per acre*	*Percent*	*Percent*
6	4	2	77
5	6	3	59
9	15	8	58
2	28	15	62
20	90	45	49
19	109	51	54
16	118	51	48
Indian ricegrass:			
9	5	3	73
19	6	3	92
16	7	3	91
20	8	4	82
2	9	5	77
5	19	10	60
6	21	11	66
Galleta:			
6	9	8	29
19	12	6	73
20	14	7	58
16	15	7	65
5	25	13	32
9	25	14	39
2	26	14	54
Sand dropseed:			
16	[1]	[2]	48
19	1	[2]	57
20	6	4	28
6	24	12	9
5	31	16	8
2	37	21	20
9	56	30	11

[1] Less than 1 pound per acre.
[2] Less than 1 percent.

The degree of use of a grass species is affected by the relative availability of herbage of other grasses. Sheep strive to include a certain amount of grass in their diet. If they cannot obtain it from the choice Indian ricegrass, they eat more galleta and sand dropseed. Utilization of galleta and sand dropseed was low in pastures 5 and 6, where Indian ricegrass yields were the greatest. In pastures 16, 19, and 20, where all three grasses were most heavily grazed, yields of Indian ricegrass and the other two grasses were relatively low.

Utilization under heavy and light intensities shows the same general relation to herbage yields as that under moderate grazing. For example, under heavy grazing utilization of winterfat was 80 percent in pastures where it comprised only 10 percent of the total herbage and 58 to 64 percent in areas where it made up 25 to 30 percent of the total herbage. Under light grazing about the same relation existed between utilization and herbage yields, although the spread in utilization percentage was not as pronounced as under moderate and heavy grazing.

The utilization of highly palatable species, on ranges where they made up only a relatively small part of the total herbage, was often excessive before sheep would eat much of the herbage produced by less desirable plants. Because of the wide variations in utilization associated with the relative herbage production of the palatable forage species, it is necessary to govern the stocking rate not only on the presence of these species, but also on the relative yields of the species within the plant cover. On depleted ranges where desirable forage species constitute an extremely small proportion of the herbage, stocking rates must necessarily be low enough to permit these scarce species to increase.

Influence of Grazing Intensity

On the experimental range pastures three degrees of grazing—light, moderate, and heavy—were applied. The plan was to maintain fairly uniform utilization of the herbage produced the previous summer by three key forage species. Planned utilization by weight under moderate grazing was 75 percent for Indian ricegrass and 50 percent for winterfat and bud sagebrush.

The desired intensity of grazing for the various range pastures was obtained and controlled reasonably well by varying the stocking each year on the basis of October herbage estimates. The moderately grazed pastures were stocked at an average rate of approximately 14 sheep-days per acre. Pastures designated as heavily grazed had about 25 percent heavier stocking (17 sheep-days per acre) and those lightly grazed 30 percent lighter (10 sheep-days per acre) than those grazed at moderate intensity.

The average yearly percentages of utilization of the herbage of the major forage species, obtained under the three intensities of grazing for the period 1935–46, are given in table 5. Utilization of the various species under light and heavy grazing was not uniformly 25 percent higher or 30 percent lower than that obtained under moderate grazing as might have been assumed would be the case under the plan of stocking. Utilization of winterfat under moderate grazing, for example, was only slightly above that under light grazing. However, in heavily stocked pastures sheep ate 11 percent more of the winterfat herbage than in moderately stocked pastures. This represented approximately 20 percent greater use. There was a similar spread in the utilization of Indian ricegrass between the three intensities of grazing. With light stocking sheep ate only small amounts of galleta and sand dropseed, 25 and 9 percent of the herbage, respectively. As the grazing intensity increased they consumed more and more of these species. Under heavy grazing, utilization of galleta herbage was 67 percent and sand dropseed 40 percent.

The utilization of the three grasses under the three intensities of grazing was interrelated. In lightly stocked pastures the sheep utilized 65 percent of the choice Indian ricegrass and only 25 and 9 percent of galleta and sand dropseed, respectively. With moderate stocking the sheep ate more of the desirable portions of Indian ricegrass and also considerable quantities of galleta and sand dropseed. In heavily stocked pastures sheep used all the edible parts of the Indian ricegrass and were forced to eat much more of the galleta and sand dropseed herbage in addition.

Under heavy grazing, the desirable forage species were closely grazed and often seriously injured or killed. As a result subsequent yields were often impaired. Sheep were then forced to eat large amounts of herbage from the less desirable species.

Shadscale, which is protected by thorns or spines, was utilized about equally under light and moderate grazing and only slightly more under heavy grazing.

The average utilization by sheep of winterfat, bud sagebrush, and Indian ricegrass, the three key species, under moderate grazing was fairly close to the predetermined plan. The average percentages of utilization obtained for winterfat, bud sagebrush, and Indian ricegrass were 55, 52, and 76 percent, respectively. Wide variations occurred from year to year, however, and utilization of the individual species varied independently. For example, the lowest utilization obtained under moderate grazing for winterfat was in 1937–38, while the lowest utilization of bud sagebrush occurred in 1943–44 when utilization of both Indian ricegrass and winterfat was relatively high. In 1945–46 when utilization of winterfat was just below average, that of both bud sagebrush and Indian ricegrass reached a maximum.

Because wide fluctuations in utilization occur from year to year, utilization standards established as grazing guides should provide for allowances to compensate for variations in vegetation and production.

PRECIPITATION AND ITS INFLUENCE ON VEGETATION

Range plant growth and herbage production are markedly influenced by both annual and seasonal fluctuations in precipitation. Low and extremely variable precipitation is typical of the winter ranges throughout the Intermountain region. Annual precipitation on winter ranges is usually less than 10 inches a year. At the Desert Experimental Range mean annual precipitation (January to December) was 6.64 inches for the period 1934–47. This low annual precipitation is the chief factor limiting plant growth and consequently herbage production.

Precipitation Records

Precipitation records at the Desert Experimental Range began in 1934. For comparison with records of longer duration, data for the experimental range and for weather stations at Modena and Deseret, Utah, are charted in figure 8. These two stations are located relatively near the experimental range, one 55 miles south, and the other 75 miles northeast.

TABLE 5.—*Average utilization of herbage (in percent) of major forage species in range pastures at three intensities of grazing, 1935–46*

Grazing period	Winterfat			Bud sagebrush			Shadscale			Indian ricegrass			Galleta			Sand dropseed			Globemallow		
	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.
1935–36	48	49	54	53	63	65	24	26	28	65	73	86	23	47	54	9	20	41	66	72	80
1936–37	51	55	64	60	50	68	19	17	35	65	72	82	17	47	47	16	17	22	70	66	75
1937–38	40	42	55	36	37	62	18	17	23	68	69	77	23	39	47	8	29	29	68	75	81
1938–39	40	46	51	49	54	76	20	20	24	56	65	78	7	26	47	1	12	7	49	70	79
1939–40	62	62	83	61	67	92	22	30	33	60	76	94	18	39	65	5	22	58	50	70	94
1940–41	45	52	64	32	41	49	16	19	24	56	79	95	34	55	80	12	29	52	63	75	90
1941–42	62	65	81	56	55	81	22	22	28	74	78	88	16	36	73	8	20	54	79	85	98
1942–43	62	67	78	45	44	59	19	22	29	50	75	92	34	66	83	8	25	56	74	85	98
1943–44	57	61	78	38	34	55	19	18	26	79	88	98	37	60	78	10	20	48	87	95	99
1944–45	36	55	65	48	57	70	21	23	29	55	71	90	33	63	83	19	49	77	62	80	90
1945–46	38	51	57	58	69	76	16	18	20	82	90	93	37	65	81	7	26	66	63	90	94
Average	49	55	66	49	52	68	20	21	28	65	76	88	25	49	67	9	24	40	66	78	89

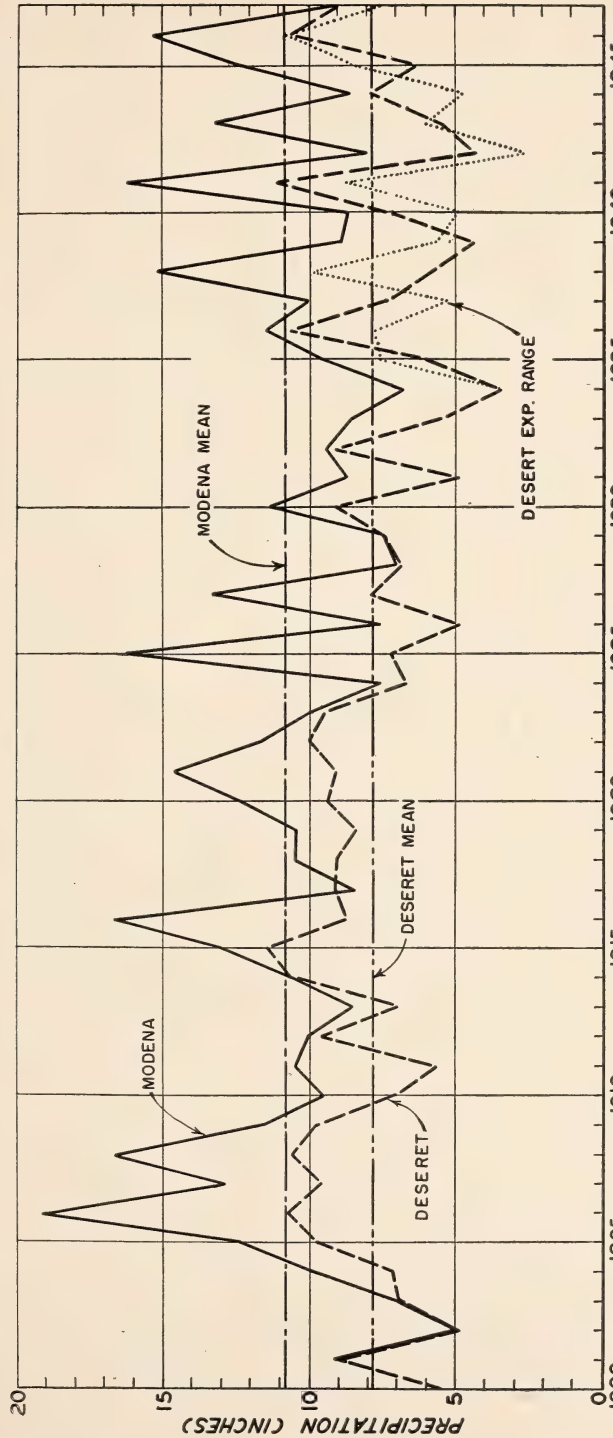

FIGURE 8.—Annual precipitation at the Desert Experimental Range and at Modena and Deseret, Utah (U. S. Weather Bureau records).

Mean precipitation at Modena for the period of record (1901–47) was 10.83 inches; at Deseret (1900–47) it was 7.84 inches. Means at both places—10.85 and 7.10 inches, respectively—for the period of study, 1934–47, compare rather closely with these figures. It is therefore reasonable to believe that mean precipitation at the Desert Experimental Range during the period of study is fairly representative of what might be expected over a longer period of time. Fluctuations in yearly amounts at all three locations followed a similar pattern, with few exceptions, during the period 1934–47. Fluctuations at Modena and Deseret were also similar in pattern during the longer period of record.

Rainfall data at the experimental range headquarters have been tabulated by 3-month periods for a 12-month rainfall year, from October 1 to September 30, because plant growth on the winter range begins about March or April and almost all growth is completed before the end of September (table 6). Precipitation for October to December is considered as contributing to the next year's growth. On this basis mean annual precipitation at the Desert Experimental Range was 6.69 inches for the period of the study, with a minimum of 3.78 inches in 1941–42 and a maximum of 11.10 inches in 1946–47. Precipitation was above average in only 5 of the 13 years.

TABLE 6.—*Seasonal and yearly precipitation (inches) at Desert Experimental Range headquarters, October 1 to September 30, 1934–47*

Period	Oct.–Dec.	Jan.–March	Apr.–June	July–Sept.	Total
1934–35	0.59	0.87	2.42	4.00	7.88
1935–36	.31	1.62	.21	4.20	6.34
1936–37	1.64	.87	1.05	2.28	5.84
1937–38	1.08	1.52	3.41	2.81	8.82
1938–39	2.05	.86	2.47	1.28	6.66
1939–40	.98	1.49	.53	1.62	4.62
1940–41	1.18	1.51	3.29	1.74	7.72
1941–42	2.15	.32	.50	.81	3.78
1942–43	.97	1.02	1.27	1.12	4.38
1943–44	2.62	.86	2.45	.26	6.19
1944–45	1.14	1.49	2.15	3.75	8.53
1945–46	1.06	.29	1.47	2.35	5.17
1946–47	6.74	.08	2.78	1.50	11.10
Average	1.73	.98	1.85	2.13	6.69

Seasonal precipitation fluctuated widely. In general, its pattern and seasonal distribution showed little consistency. Less than one-fourth inch of precipitation occurred in many individual months, and less than one-half inch in several of the 3-month periods. Precipitation for the October to December period varied from 0.31 inch to 6.74 inches. Precipitation for the January–March period averaged only 0.98 inch. This was consistently a dry period.

Precipitation for the two growing periods, April to June and July to September, was relatively high, averaging about 2.00 inches for each period. During the latter period rainfall was cyclic in character. It was relatively high during the first 4 years, low from 1939 to 1944, and relatively high again in the next 2 years.

Much of the winter precipitation comes as snow. This seldom exceeds 4 or 5 inches in depth except in the foothills and desert mountains. Often the storms are erratic and poorly distributed. Since sheep depend largely on snow for water, ranges are often used unevenly. In severe winters or during heavy winter storms the snow often becomes too deep or too firmly crusted to permit effective grazing. If deep snow persists over large areas, the sheep become extremely poor and often die because they are unable to obtain sufficient forage. In the last 20 years such conditions have occurred several times, notably in the winters of 1931–32, 1936–37, 1948–49, and 1951–52.

When strong winds accompany a snowstorm or follow immediately afterwards, deep snowdrifts are formed. These hamper the movement of sheep and limit grazing to ridges blown free of snow.

According to rain-gage records, summer storms are also localized and often occur as torrential downpours of high intensity. For example, on May 2, 1935, 1.20 inches of precipitation fell in less than 20 minutes in the south end of Wah Wah Valley. Areas a short distance away received no rain. On July 28, 1936, Antelope Valley received 1.57 inches of rain in 23 minutes, but there was none at the Desert Experimental Range headquarters 6 miles to the east. During such torrential storms much of the precipitation is lost in runoff and consequently is not available for plant growth.

Influence of Precipitation on Production

Forage plants on the winter range consist of a mixture of early- and late-growing species. Many of them, including the shrubs and such grasses as Indian ricegrass, squirreltail, and bearded bluebunch wheatgrass, begin to grow in the latter part of March or in early April, provided soil, moisture, and weather conditions are favorable. Some of these species continue to grow throughout the summer if rainfall is adequately distributed. In dry summers plant growth stops, the herbage becomes dry and brittle, and frequently the plants fail to produce flowers or seed. Some forage plants, primarily such annual forbs as Russian-thistle and such grasses as galleta, sand dropseed, and blue grama, begin to grow in May and June. These species generally depend on summer precipitation to make their growth. Almost all plant growth on the winter range is completed by September, though late rains often freshen and soften the herbage.

TOTAL HERBAGE YIELD

The total air-dry herbage yield was estimated annually on each range pasture. These data were averaged and used to determine the relation between production and precipitation. In most years herbage production was estimated directly. However, yields for the first 3 years were calculated from plant density; and the production for 1946, when no data were taken, was calculated from the relation of production to precipitation.

Air-dry herbage yield on all pastures for the period 1935–47 averaged 219 pounds per acre. The maximum yield of 468 pounds per acre was recorded in October 1947, immediately following the 12-month period

of highest precipitation. This was more than six times the minimum yield of 75 pounds per acre, which occurred in October 1943 following two consecutive years with below-average precipitation.

The total herbage yield on the winter range as measured in October was found to be closely related to the precipitation during the preceding 12 months. This relation of herbage yield to precipitation is shown in figure 9. Within the limits of variation in precipitation observed at the Desert Experimental Range, herbage production increased about 46 pounds per acre (dry weight) with each additional inch of precipitation.

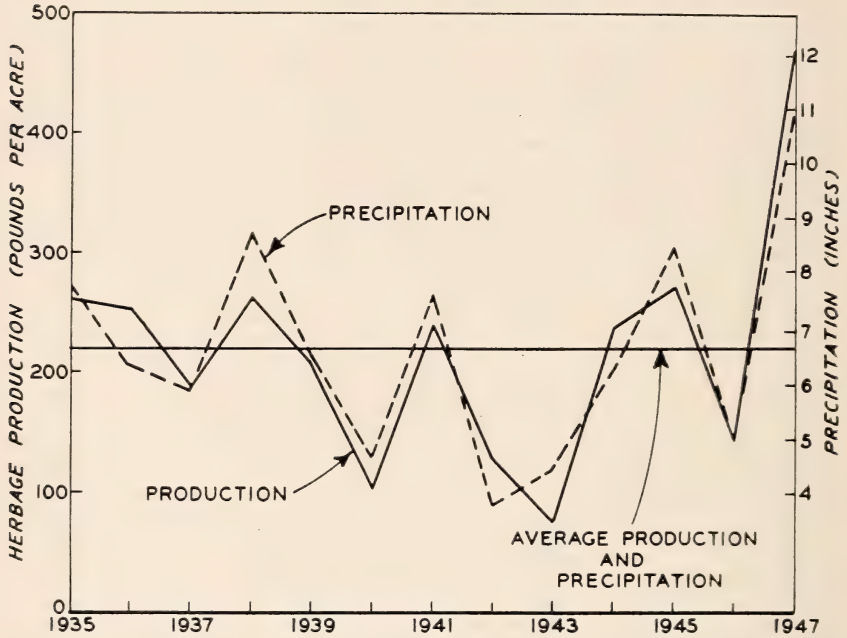

FIGURE 9.—Average annual air-dry herbage production as measured in October in all range pastures at the Desert Experimental Range and precipitation during the preceding 12 months, 1935–47.

The close relation between precipitation and herbage production provides a basis for estimating October herbage yields from the amount of precipitation received each year[3] (fig. 10). Reliable estimates of herbage yield for years when rainfall is between 4 and 11 inches can be made directly from the chart. Herbage production increases with precipitation as indicated by the slope of the estimating line. The relation between the measured herbage production and precipitation for individual years is shown by the dots.

[3] Equation for estimating herbage yield from previous 12-month precipitation (calculated from data for 1938–45 and 1947) is:

$$Ye = -92.46 + 45.80x \text{ with a standard error of estimate of } \pm 41.25$$

where Ye is the expected air-dry herbage yield in pounds per acre and x is the 12-month precipitation in inches. Correlation between herbage production and precipitation for this period of measurement was $r = +0.944$.

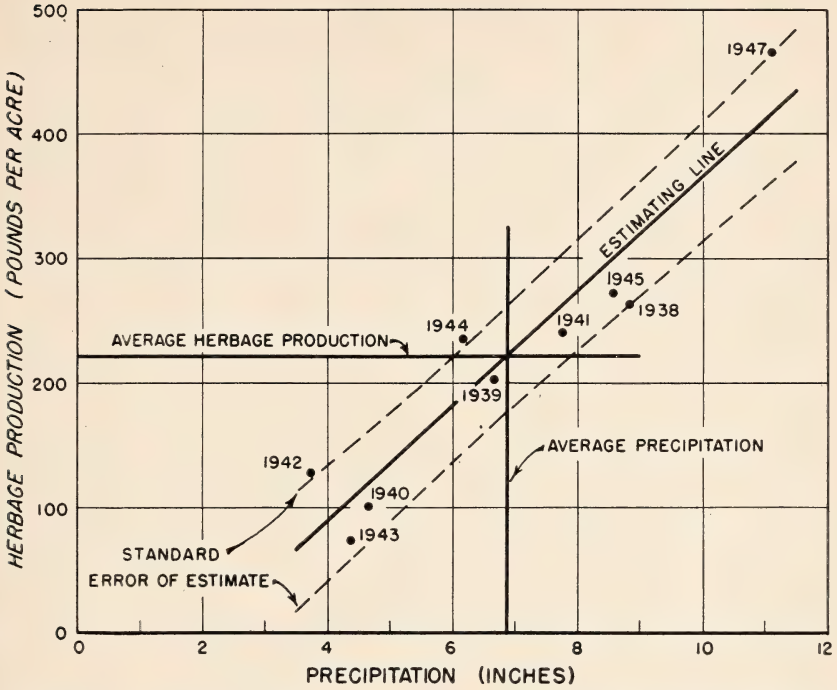

FIGURE 10.—Relation of October herbage production to precipitation during the preceding 12 months at the Desert Experimental Range. This chart can be used to estimate herbage production from the precipitation in other years.

To use the chart a vertical line is projected upward from the amount of precipitation until it intersects the estimating line. A horizontal line is then projected across to the left-hand margin where an estimate of herbage production can be read. As an example, the average herbage production expected for a year with rainfall of 8 inches would be approximately 275 pounds per acre, as read from the chart. The actual production obtained may be higher or lower than the estimated amount, depending on seasonal distribution and character of the precipitation and whether or not precipitation was above or below average the preceding year. However, in about two-thirds of the years, the actual herbage yields obtained would not be expected to vary more than 41 to 50 pounds above or below the estimated amounts. These limits are indicated by the dashed lines in figure 10.

This method of prediction has been useful in providing an estimate of herbage production, without the time-consuming necessity of sampling the vegetation, before sheep reach the winter ranges. Herd owners have thus been enabled to purchase supplemental feeds or otherwise provide for anticipated short forage. Although the data apply particularly to the range area at the Desert Experimental Range, they can also be applied to other winter range areas where the vegetation, condition of the range, and amounts of rainfall are similar. Where these conditions are not similar, relationships could be developed for specific areas from herbage weight determinations made over a period of years.

Seasonal distribution of precipitation also influences herbage yields. Most of the fall and winter precipitation filters into the soil, where it is retained and used by forage plants to make early spring growth. In contrast, much of the summer precipitation, which comes as localized torrential storms, is lost as surface runoff. Also, during the summer months losses by evaporation are large because temperatures are high and desiccating winds are common. Analysis of data from the pastures where the vegetation is chiefly shadscale, winterfat, galleta, and dropseed indicates that precipitation between October and December was about twice as effective in the production of total herbage as that between April and September, and that precipitation during the other three months, January to March, was about one and one-half times as effective.

YIELD OF INDIVIDUAL SPECIES

Individual species respond differently to precipitation. Yield of shadscale and winterfat in October, like total herbage, was found to be closely associated with precipitation during the preceding 12 months (fig. 11). These two species produced more than half of the total herbage in the experimental pastures and therefore largely influenced total production. Production of these two shrubs fluctuated widely from year to year. Yields of shadscale followed changes in precipitation more closely than did winterfat or any other species.

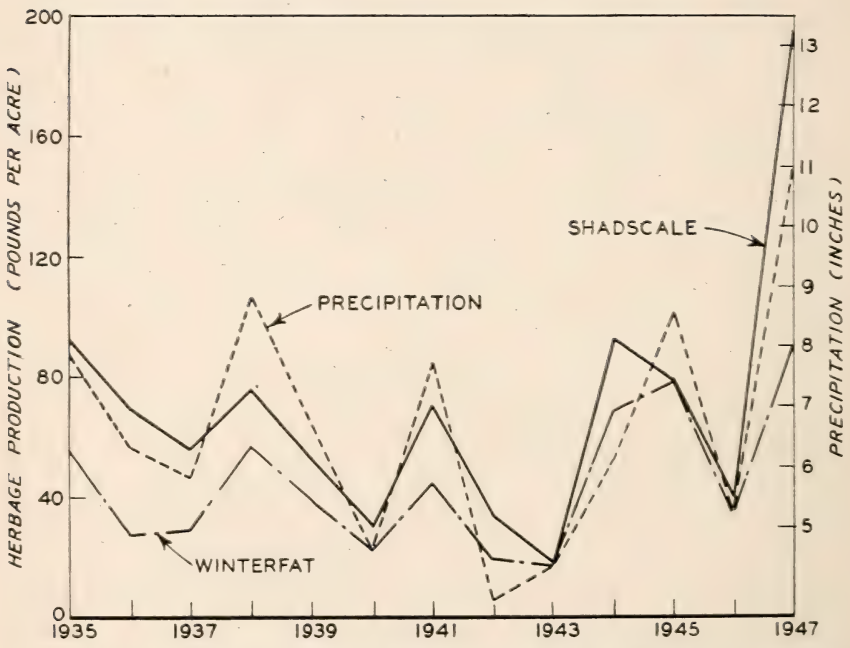

FIGURE 11.—Average herbage production in October of the major shrubs, winterfat and shadscale, in the 20 experimental pastures in relation to rainfall during the preceding 12 months, 1935–47.

Mortality of shadscale was relatively high during the drought period 1942–43, when it was estimated that 20 to 30 percent of the shadscale plants died. During this same period very little loss occurred in other forage species. Although production of shadscale and winterfat each declined to 18 pounds per acre in 1943 following 2 years of drought accompanied by heavy mortality of shadscale, they responded quickly to favorable precipitation the following years. In 1944 with just below average precipitation, 2.62 inches of which came in the October–December period and 2.45 inches in the April–June period, the dormant winterfat plants quickly revived and many shadscale seedlings appeared. In that year shadscale and winterfat produced 93 and 69 pounds per acre, respectively. By October of 1947, following 4 years of average or above-average precipitation, yields of these two shrubs reached a maximum. Winterfat produced about 90 pounds per acre and shadscale 195 pounds, more than twice their average yield. This demonstrates the remarkable ability of the winter range vegetation to recover from the effects of drought.

The three major grasses—Indian ricegrass, galleta, and sand dropseed—showed differing responses to variations in precipitation, but in general their yields were closely correlated with previous 15-month precipitation (fig. 12) rather than with the previous 12-month precipitation. Analysis of data for the period 1938–45 and for 1947 showed that sand dropseed followed variations in 15-month precipitation most closely. In 1936, yield of this species as calculated from plant density was unusually high (59 pounds per acre). Most of the increase was due to the numerous seedlings produced in 1935 and 1936 as a result of favorable late spring and summer rains. Many of these seedlings failed to survive through 1937.

Yields of galleta followed variations in 15-month precipitation closely but somewhat less so than those of sand dropseed. Relatively high yields of both these grasses occurred in 1938, 1939, 1941, and 1947, all years with high spring and summer rainfall.

Production of Indian ricegrass showed the lowest correlation with 15-month precipitation. In 1938, with prior 15-month rainfall of 11.10 inches, yield of Indian ricegrass was 17 pounds per acre; in 1939, with 2 inches less rainfall, yield was the same; and in 1945, with 8.79 inches, yield was only 9 pounds.

Yields of all three grasses fluctuated with precipitation but showed a general decline from 1935 to 1942–43, during a period generally characterized by below-average rainfall. The lowest yields of all grass species occurred in 1943 following the 2 years of drought. After the drought period production increased rather rapidly until 1947 when yields were highest. Although grass yields improved following the drought, the recovery was not nearly as great as that of winterfat and shadscale.

INFLUENCE OF GRAZING INTENSITY ON VEGETATION

The great fluctuations in plant growth due to differences in precipitation from year to year tend to overshadow the effects of grazing, particularly during short periods of time. To segregate one effect from the other, it is necessary to compare results obtained under different

intensities of grazing where other conditions, such as the amount of precipitation received and the initial kind, distribution, and amount of vegetation, are as nearly alike as possible. The period of comparison should be of fairly long duration, since the effects of grazing are cumulative, usually being small at first and becoming discernible or even subject to analysis only after a considerable lapse of time.

Vegetation at the Desert Experimental Range was studied primarily as it occurred within the fairly large subtypes characteristic of winter range. These vegetal groups provide convenient units for the observation of changes in relation to grazing intensity. Even more important, they are natural subdivisions within which grazing practices may be modified to bring about improvement in the plant cover.

Shadscale and Winterfat Subtypes

Effects of grazing intensity on the shadscale and winterfat subtypes were studied in the experimental range pastures where the vegetation was composed primarily of three subtypes, namely, shadscale-winterfat-grass, shadscale-grass, and winterfat. Each of these three subtypes were represented in some of the range pastures under each of the three intensities of grazing. During the experimental studies the sheep grazed the entire area of the range pastures and did not noticeably show preference for any of the plant subtypes. Estimates of herbage yield were made yearly for all species found on the range pastures.

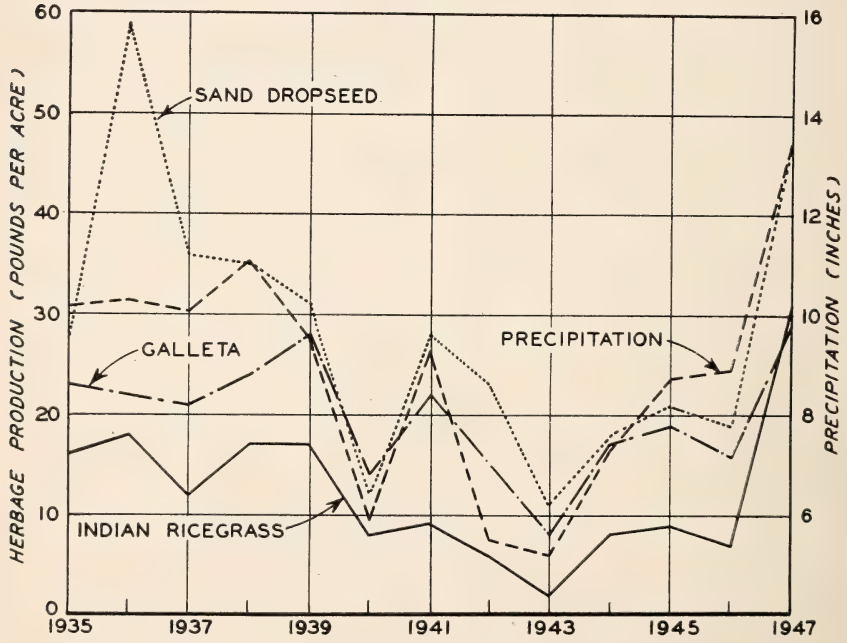

Figure 12.—Average herbage production in October of the major grasses—Indian ricegrass, galleta, and sand dropseed—in the 20 experimental pastures in relation to rainfall during the preceding 15 months, 1935–47.

Yield trends, for total herbage and for individual species under light, moderate, and heavy intensities of grazing, were computed by the least-squares method described by Snedecor (*18*).

TOTAL PRODUCTION

Total annual herbage production of all plants within shadscale and winterfat subtypes as represented in the experimental range pastures for the three intensities of grazing is shown in figure 13. Total production is the sum of the increases and decreases of individual species and therefore shows the over-all average difference between grazing treatments.

When the studies were begun in 1935, average herbage production in the range pastures assigned at random to light and moderate grazing was somewhat lower than in those assigned to heavy grazing. Initial yields, calculated from density estimates, were 232, 271, and 286 pounds per acre, respectively, for light, moderate, and heavy grazing.

Herbage production dropped during the next 2 years under heavy grazing. Production also showed a decline under light and moderate grazing in 1937 following a year with below-average precipitation. Yields under all three intensities rose in 1938 after favorable precipitation. In every year following 1938 more herbage was produced on the moderately grazed range than on that heavily grazed, despite the fact

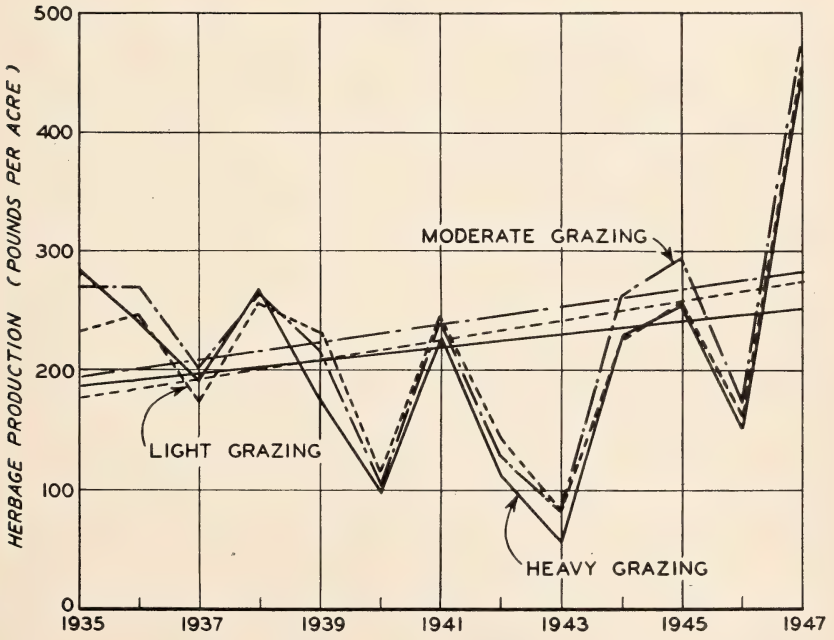

FIGURE 13.—Average annual herbage production of all plants and calculated trend of production in 6 lightly, 7 moderately, and 7 heavily grazed range pastures within shadscale and winterfat subtypes, 1935–47.

that the initial production was 15 pounds per acre lower. Under light grazing, yields increased enough to overcome the original deficit of 54 pounds per acre and remained above those on the heavily grazed range except for a slight deficit in 1944.

It is especially noteworthy that, during the 5 years from 1939 to 1943 which included 4 years with below-average precipitation, yields under moderate grazing exceeded those under heavy. In 1943 after 2 years of drought, total production dropped to its lowest point under all grazing intensities, being 84, 83, and 58 pounds per acre for light, moderate, and heavy grazing. Herbage yields under light and moderate grazing thus were 45 and 43 percent greater than the yield under heavy grazing.

Calculated yield trends for the period of study are shown as straight lines in figure 13. They were upward for all three intensities of grazing, but more so for light and moderate grazing than for heavy grazing—54 and 46 percent as against 34 percent for the 13-year period.

Increases in total herbage production under light and moderate grazing as compared with heavy grazing are not easily detected on winter ranges. The results at the Desert Experimental Range, however, are comparable with those obtained on other classes of rangeland where production is generally higher, such as the spring-fall sagebrush-wheatgrass ranges in Idaho (*4*, *13*), yearlong shortgrass range in Montana (*23*), and black grama range in New Mexico (*10*).

INDIVIDUAL SPECIES

Yield of the major forage plants during the period of study under each intensity of grazing is given in table 7. For effective interpretation of yield trends under the three intensities of grazing, it is important to consider the average utilization that each species received (table 5).

Winterfat showed the greatest changes in relation to grazing intensity during the 13-year period of study (fig. 14). Under moderate grazing this species made the greatest increase, and because of its relative abundance it was largely responsible for the increase obtained in total herbage.

Initial yields of winterfat, as calculated from density estimates, were 19, 53, and 96 pounds an acre in the range pastures assigned to light, moderate, and heavy grazing. Despite these great initial differences, production under moderate grazing increased enough to surpass that under heavy grazing in 1939. During the next 3 years, yields were about equal for both intensities, that for moderate grazing being slightly below heavy. After the second successive drought year in 1943, yields under moderate grazing again exceeded those under heavy grazing and remained above in the last 4 years of study.

Yields of winterfat under light grazing were generally upward, with declines during the dry years. The rate of recovery was slow, which is not surprising in view of the low initial production.

Calculated yield trends of winterfat for all treatments, also shown in figure 14, were upward—239, 321, and 33 percent, respectively—for light, moderate, and heavy grazing. Average utilization of winterfat herbage for the 13-year period was 49, 55, and 66 percent. The heaviest use occurred in the low production years from 1939 to 1943.

TABLE 7.—*Yearly air-dry herbage production (pounds per acre) of major forage species in range pastures, on shadscale and winterfat subtypes, grazed at three intensities, 1935–47* [1]

Year	Winterfat			Bud sagebrush			Shadscale			Indian ricegrass			Galleta			Sand dropseed			Globemallow		
	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.	Lt.	Mod.	Hvy.
1935	19	53	96	4	3	3	71	96	110	17	21	11	29	22	19	40	28	13	6	5	5
1936	15	16	50	4	6	4	49	71	89	16	29	9	29	22	16	80	64	34	11	12	9
1937	13	30	45	2	3	2	38	52	73	10	21	6	24	23	15	49	34	24	4	4	4
1938	31	63	76	3	3	3	64	71	92	17	19	15	34	24	15	45	34	25	9	7	8
1939	26	47	43	2	2	2	53	47	60	19	21	10	45	27	12	44	30	20	7	6	6
1940	13	26	31	3	3	2	27	26	33	10	9	6	20	14	7	18	11	8	2	1	2
1941	32	48	54	6	6	4	66	82	83	10	10	8	30	24	13	34	30	20	3	3	4
1942	12	24	25	3	3	2	30	33	37	7	5	5	21	15	9	33	21	15	2	2	2
1943	12	22	18	2	2	1	17	18	18	3	2	2	11	8	4	17	11	6	1	1	1
1944	39	95	73	2	2	1	80	90	109	10	8	5	23	18	9	28	18	9	4	2	2
1945	44	101	90	4	3	2	76	79	80	10	9	8	23	20	13	29	22	13	8	6	5
1946	20	40	38	3	3	2	36	40	45	8	8	6	23	16	8	26	18	12	3	2	2
1947	53	114	102	6	5	4	190	176	218	32	30	30	30	28	29	65	49	29	10	8	9

[1] Yields for 1935–37 calculated from relation of density and yield; for 1938–45 and 1947 by the weight-estimate method; those for 1946 calculated from relation of precipitation and yield.

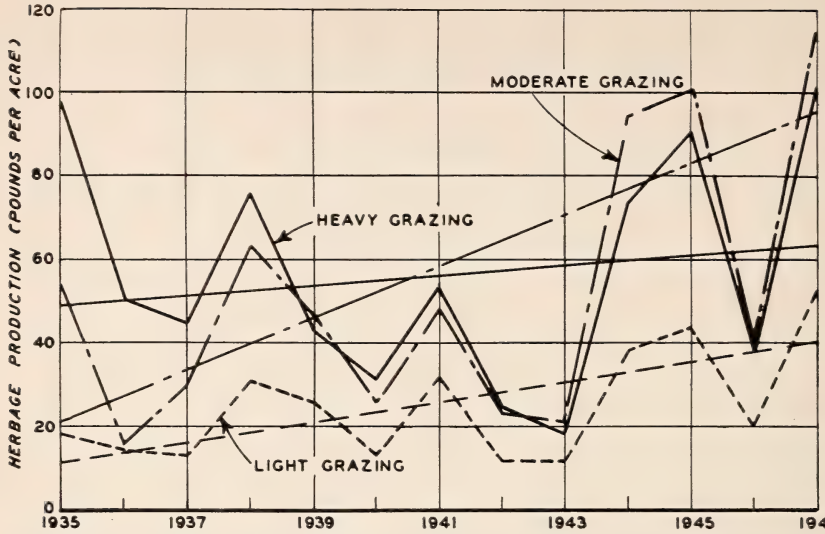

FIGURE 14.—Average annual herbage production of winterfat and calculated trend of production in 6 lightly, 7 moderately, and 7 heavily grazed range pastures, 1935–47.

Yield of shadscale, the most abundant species, showed upward trends under all intensities of grazing. The trends were slightly greater with moderate, and considerably greater with light grazing than with heavy. This was probably because more of the seed was eaten on the heavily grazed range, thus decreasing the amount of reproduction. Average utilization under light, moderate, and heavy grazing was 20, 21, and 28 percent; plant vigor was therefore probably not diminished at any intensity.

Indian ricegrass showed little trend in relation to the different degrees of grazing. In these subtypes it makes up only a small proportion of the vegetation and was overgrazed at least in some years in all pastures. Average utilization under light, moderate, and heavy grazing was 65, 76, and 88 percent. The trend in production was downward for all three degrees of use to 1943. In the dry years of 1942 and 1943 yields, although generally low, were slightly higher under light and moderate use than under heavy. The rate of recovery after 1943 was somewhat more rapid under the first two intensities.

Galleta yields were greater in all years under light and moderate intensity than under heavy. The three intensities showed respective downward trends of 27, 14, and 35 percent. The differences between trends were not statistically significant. Average utilization was 25, 49, and 67 percent under light, moderate, and heavy grazing. Only in the years of 1939 and 1941, when favorable summer rainfall occurred and production increased, did differences ascribable to grazing treatment emerge. In both of these years production increased more with light and moderate grazing than with heavy grazing.

Production of sand dropseed also showed slight downward trends for all grazing treatments, although this species was utilized only 9,

24, and 40 percent under light, moderate, and heavy grazing. Bud sagebrush and other minor species, including all forbs, did not show any consistent trend in grazing intensity during the period of study.

Shadscale-Indian Ricegrass Subtype

A shadscale-Indian ricegrass subtype was divided by fencing when the experimental range was established in 1934. This subtype extended from inside the northeast corner of the fenced allotments of the experimental range into the unfenced range beyond. On both areas the vegetation was badly depleted and production was low. Amounts of herbage and usable forage were recorded in 1937 after the two areas had been subjected to grazing at different levels for 4 years (table 8).

Table 8.—*Production per acre of air-dry herbage and forage within a shadscale-Indian ricegrass subtype after 4 years' grazing at moderate and heavy intensities, 1937*

Species	Moderate grazing		Heavy grazing	
	Herbage	Forage	Herbage	Forage
Shrubs:	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Shadscale	152.5	38.1	148.4	37.1
Black sagebrush	11.5	8.1	2.5	1.8
Winterfat	30.7	18.4	4.5	2.7
Other	12.8	3.8	21.5	6.5
All shrubs	207.5	68.4	176.9	48.1
Grasses:				
Indian ricegrass	166.7	125.0	31.4	23.6
Other	14.8	4.4	1.4	.4
All grasses	181.5	129.4	32.8	24.0
Forbs	(1)	(1)	(1)	(1)
Total	389.0	197.8	209.7	72.1

[1] Less than 0.1 pound per acre.

By 1937, after 4 years of grazing treatment, total herbage production on the moderately grazed experimental range area was almost twice as great as on the adjacent heavily grazed area. Production of the palatable species—winterfat, black sagebrush, and Indian ricegrass—was far greater under moderate grazing. Black sagebrush produced about five times more herbage and winterfat almost seven times more on the moderately grazed range than on the heavily grazed.

In 1934, a drought year, Indian ricegrass produced about 30 percent of the total herbage. By 1937 it produced 167 pounds of herbage per acre, more than 40 percent of the total within the moderately grazed area, but it produced only 31 pounds per acre or about 15 percent of total herbage yield under heavy grazing. The great increase under moderate grazing made Indian ricegrass by far the highest producer of

forage within this subtype. This improvement is in marked contrast to the results obtained on the winterfat and shadscale subtypes where Indian ricegrass formed a much smaller proportion of the plant cover.

In 1942 when further comparisons were made, Indian ricegrass was still the highest producer of forage on the moderately grazed shadscale-Indian ricegrass subtype. The number of plants per unit of area was about 50 percent greater than on the heavily grazed range. Fifty plants were harvested at random from both the moderately and heavily grazed portions of the subtype and compared (fig. 15). Those from the moderately grazed range averaged 13½ inches in height and produced 17.7 grams of air-dry herbage per plant as against 10½ inches and 6.7 grams for those from the heavily grazed range. Seed production was 3.2 times larger under moderate grazing than under heavy.

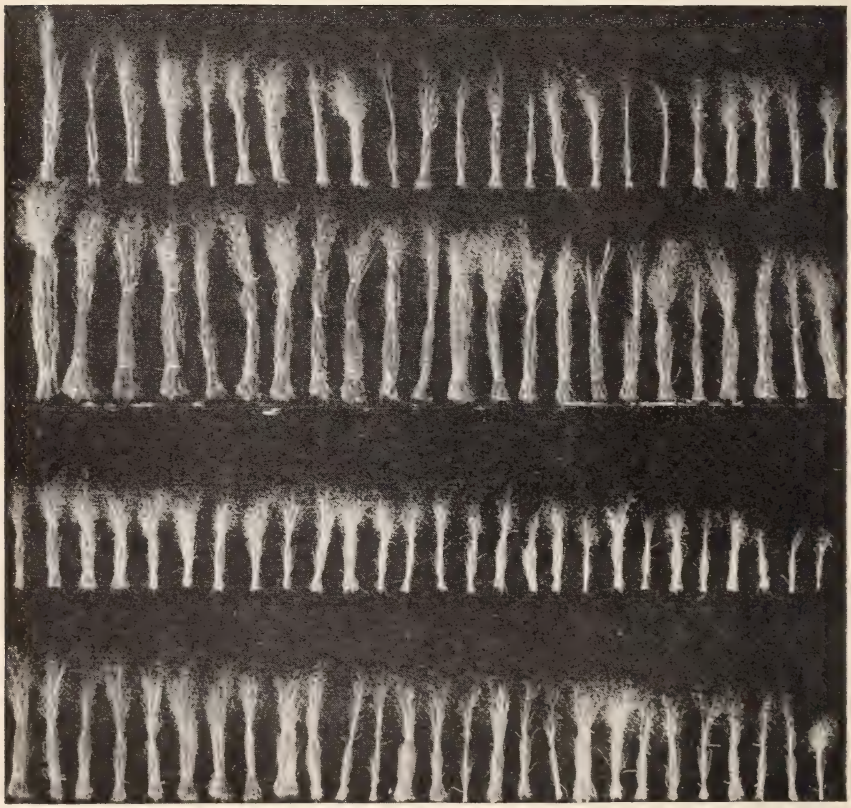

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FIGURE 15.—Fifty Indian ricegrass plants harvested at random from heavily grazed range (top and third rows), and fifty from moderately grazed range (second and bottom rows) in the shadscale-Indian ricegrass subtype.

The more abundant and better-filled seeds produced by vigorous plants obviously favor the establishment of a greater number of seedlings. In the case of Indian ricegrass, however, years of good seed

production are very infrequent. They occurred only twice during the 13 years of study—in 1937 and 1941—when spring and summer rainfall was greater than usual. To insure the survival and growth of seedlings under such circumstances, moderate rates of stocking are virtually mandatory not only after establishment but before (fig. 16).

F–427012

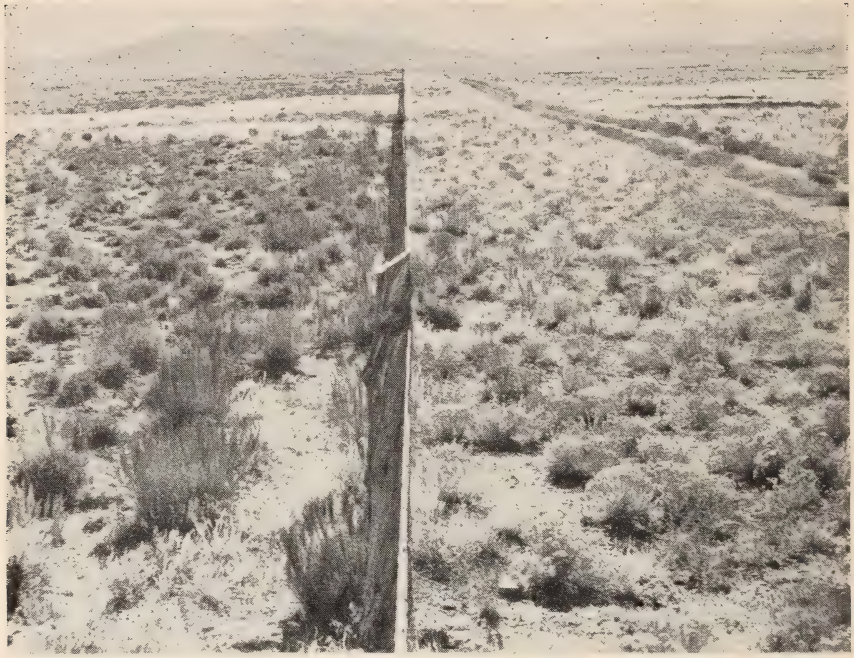
FIGURE 16.—Many Indian ricegrass seedlings became established on this deteriorated winter range after 4 years of conservative grazing and a favorable seed year in 1941.

Black Sagebrush Subtypes

In 1934 a large range area in Antelope Valley that was potentially a black sagebrush-winterfat subtype was divided and one part of the area was fenced. At the time of fencing the two parts were essentially similar, the vegetation consisting primarily of winterfat and small rabbitbrush, with small amounts of black sagebrush and grass (table 9). One part was placed under moderate grazing while heavy grazing was continued on the other part. Herbage production was recorded for these two areas in 1934, 1938, and 1947.

Following 1934, a year of low rainfall, yields of herbage on both the moderately and heavily grazed parts of the subtype increased. However, the computed yields of forage show a marked increase under moderate grazing. The yield was twice as large in 1938 and more than three times as large in 1947 as that produced in 1934. Meanwhile, the amount of usable forage on the heavily grazed area remained practically unchanged (fig. 17), despite the increase in total herbage. The estimates of usable forage were obtained by multiplying the herbage yield for each species on the area by its utilization percentage listed in table 1.

The pronounced increase in forage on the moderately grazed range was brought about largely by a shift in the species composition and by a higher total production. Herbage production of most of the palatable



F–468701

FIGURE 17.—By 1947, after 13 years of moderate grazing, black sagebrush was the dominant species on moderately grazed range (left). Vegetation on heavily grazed range (right) was still characterized chiefly by small rabbitbrush.

species increased and that of the undesirable small rabbitbrush declined. The greatest recovery was made by black sagebrush. In 1934, yield of this highly palatable species was 21 pounds per acre, only 7 percent of the total herbage. By 1938 its production had more than doubled, largely as a result of increased vigor of the existing plants. In 1947 it produced 296 pounds per acre, almost 15 times as much as in 1934. A large part of the increased yield during this latter period came from the establishment and growth of a large number of seedlings. Through this recovery and improvement black sagebrush became the most important forage species, producing about 43 percent of the herbage and 48 percent of the forage. In contrast, black sagebrush remained a minor species on the heavily grazed range.

Yield of winterfat, the most productive species in 1934, doubled by 1938 under moderate grazing. Thereafter this species declined as black sagebrush increased. But, in spite of the decrease, the yield of winterfat in 1947 was about 50 percent greater than in 1934. On the adjacent heavily grazed range winterfat decreased about 15 percent below the 1934 yield.

Small rabbitbrush, an undesirable species which often invades heavily grazed ranges, increased moderately up to 1938 and then decreased drastically on the moderately grazed range. Under heavy grazing it increased steadily and the yield in 1947 was 268 percent greater than in 1934. On the heavily grazed range it produced nearly one-half of the total herbage in 1947.

TABLE 9.—*Herbage production per acre within a depleted black sagebrush-winterfat subtype in 1934 and after 4 and 13 years of grazing under moderate and heavy intensities* [1]

Species	Initial yield 1934	Moderate grazing		Heavy grazing	
		1938	1947	1938	1947
Shrubs:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Black sagebrush	20.6	44.7	295.8	13.8	27.5
Small rabbitbrush	66.3	100.2	28.5	161.9	243.7
Winterfat	181.1	369.6	279.4	205.2	153.4
Other	3.0	(2)	(2)	(2)	(2)
All shrubs	271.0	514.5	603.7	380.9	424.6
Grasses:					
Galleta	3.4	6.0	2.8	5.0	3.1
Indian ricegrass	9.9	14.8	40.9	11.1	18.6
Squirreltail	3.1	4.1	28.3	1.3	4.5
Other	(2)	(2)	(2)	(2)	(2)
All grasses	16.4	24.9	72.0	17.4	26.2
Forbs:					
Globemallow	(2)	4.8	2.1	(2)	4.8
Russian-thistle	(2)	(2)	6.0	3.0	96.7
Other	(2)	.9	.9	(2)	.9
All forbs	(2)	5.7	9.0	3.0	102.4
Total	287.4	545.1	684.7	401.3	553.2
Usable forage [3]	141.9	283.9	433.1	160.8	168.0

[1] Calculated from plant density data.
[2] Less than 0.1 pound per acre.
[3] Calculated from utilization records.

Grasses increased more than fourfold under moderate grazing. The greatest increases occurred in the palatable squirreltail and Indian ricegrass. Yield of squirreltail in 1947 was more than nine times and that of Indian ricegrass four times as great as in 1934. Although these species made pronounced gains, they produced only about 10 percent of the total herbage and 12 percent of the forage in 1947. These species made little gain under heavy grazing.

Production of Russian-thistle on the moderately grazed range was very low in all years. In contrast, yield of this species on the heavily grazed range in 1947 was about 97 pounds per acre, one-sixth of the total yield.

Additional observations on vegetal changes were made on a deteriorated black sagebrush-shadscale range in Snake Valley, 3 miles north of the Desert Experimental Range. A 4-acre enclosure was constructed on the range in 1937 and herbage production of all plant species was recorded on plots inside and outside in 1937, 1939, and 1947 (table 10).

TABLE 10.—*Herbage production per acre in an ungrazed enclosure and on adjacent heavily grazed range within a black sagebrush-shadscale-grass subtype at two intervals after establishment of the enclosure in 1937*

Species	Ungrazed			Heavily grazed		
	1937	1939	1947	1937	1939	1947
Shrubs:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Shadscale	118.1	104.7	238.9	120.3	168.3	319.3
Bud sagebrush	4.7	6.2	24.1	4.3	3.4	6.6
Winterfat	110.0	117.5	66.0	99.8	57.4	32.6
Black sagebrush	13.5	22.8	196.4	15.1	12.3	22.1
Other	5.2	5.5	16.0	.3	1.5	16.4
All shrubs	251.5	256.7	541.4	239.8	242.9	397.0
Grasses:						
Indian ricegrass	42.9	90.0	26.8	43.7	56.0	39.1
Galleta	16.6	3.5	2.4	26.7	5.4	5.0
Squirreltail	2.2	4.3	74.7	3.5	3.8	20.2
Other	.2	.4	6.3	.7	1.0	18.5
All grasses	61.9	98.2	110.2	74.6	66.2	82.8
Forbs	13.5	11.5	31.8	10.8	13.8	26.3
Total	326.9	366.4	683.4	325.2	322.9	506.1
Usable forage [1]	153.1	192.2	339.2	152.7	137.7	180.7

[1] Calculated from utilization records.

Yield of black sagebrush within the ungrazed enclosure rose from 13 pounds per acre in 1937 to 196 pounds in 1947, about a fifteenfold increase. This species produced only 4 percent of the herbage in 1937 and 29 percent in 1947. On the heavily grazed adjacent range it still comprised only 4 percent even though its total yield was about 50 percent greater in 1947 than in 1937. Approximately the same relative increase in black sagebrush was obtained on the moderately grazed range in Antelope Valley as in this ungrazed enclosure.

Bud sagebrush and squirreltail also made significant increases within the enclosure, in contrast to smaller gains obtained under heavy grazing. Shadscale also increased on both areas, but the increase was more pronounced on the heavily grazed range. Shadscale frequently increases on overgrazed ranges, especially where winterfat and black sagebrush are injured by excessive grazing.

Grasses were quite variable in their response. Indian ricegrass increased between 1937 and 1939 and then declined. Galleta declined throughout the entire period. Squirreltail increased remarkably on the protected area, from 2 pounds per acre in 1937 to 75 pounds in 1947. The increase under heavy grazing was not so pronounced.

The estimated usable forage more than doubled between 1937 and 1947 in the protected enclosure, whereas on the heavily grazed range forage production declined in 1939 and then increased in 1947, largely as a result of fluctuation in precipitation. Yield of forage within the enclosure in 1947 was almost twice as great as on the heavily grazed range, yet total herbage was only 35 percent greater.

Winterfat Subtype Containing Russian-Thistle

Although only minor quantities of Russian-thistle are present on the Desert Experimental Range, it has heavily invaded many depleted winterfat areas in valley bottoms elsewhere (fig. 18). In 1937 a 4-acre enclosure was constructed on such a range in Pine Valley, 7 miles south of the experimental range. At that time about 60 percent of the vegetation was Russian-thistle (table 11).

By 1940 Russian-thistle had almost disappeared within the ungrazed enclosure, but on the surrounding range it had increased and in that year produced 75 percent of the total herbage. Within the enclosure in 1947, after favorable precipitation, production of this species was only about 2 percent of the total. In contrast, it increased almost fourfold on the adjacent heavily grazed range, where it produced 402 pounds per acre or 54 percent of the total herbage.

The unpredictable behavior of Russian-thistle is illustrated by its wide yearly variations in production, even on heavily grazed range where competition was lacking. In the dry year of 1946, it produced only 0.7 pound of herbage an acre, an insignificant amount in comparison to the production of winterfat under the same conditions.

The continued suppression of Russian-thistle inside the enclosure was brought about primarily by the increases in winterfat and Indian ricegrass—both highly palatable species. By 1947 these two plants made up 90 percent of the total herbage in the enclosure, whereas the total had increased nearly 400 percent. On the heavily grazed range they produced only about one-half as much herbage as in the enclosure.

Indian ricegrass showed much the same general response in this enclosure as it did under moderate grazing. From an initial low production of about 3 percent of the total it yielded more than 25 percent of the herbage by 1946. During the next year the proportion declined to about 20 percent. This seems to be the characteristic reaction of Indian ricegrass under reduced levels of grazing—a marked increase in production at first and then a decline as the slower growing shrubs recover and become reestablished.

F–415774

Figure 18.—A heavy stand of Russian-thistle on a deteriorated winterfat range.

Although the usable forage was slightly greater on the adjacent heavily grazed range in 1937, 10 years later the estimated usable forage produced within the enclosure was 373 pounds per acre as compared with 224 pounds outside it. The heavily grazed range had the greater total herbage yield in 1947, but more than half of this was the low-value Russian-thistle, which showed a striking increase, largely because of the unusually favorable precipitation during the preceding year.

TABLE 11.—*Herbage production per acre in an ungrazed enclosure and on adjacent heavily grazed range within a winterfat subtype at three intervals after establishment of the enclosure in 1937*

Species	Ungrazed				Heavily grazed			
	1937	1940	1946	1947	1937	1940	1946	1947
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Shrubs:								
Winterfat	35.8	171.4	121.2	428.1	49.0	29.1	61.7	213.8
Other	.5	(1)	2.4	6.7	3.3	2.7	3.0	11.4
All shrubs	36.3	171.4	123.6	434.8	52.3	31.8	64.7	225.2
Grasses:								
Indian ricegrass	4.0	18.6	45.0	132.4	3.1	4.4	5.2	36.4
Galleta	12.1	49.8	5.8	21.9	9.3	7.6	3.5	24.8
Other	.4	(1)	.2	1.0	2.5	(1)	4.0	22.8
All grasses	16.5	68.4	51.0	155.3	14.9	12.0	12.7	84.0
Forbs:								
Russian-thistle	73.3	.2	0	13.9	113.2	143.0	.7	401.6
Other	3.2	10.4	.4	18.0	1.8	2.7	1.8	37.3
All forbs	76.5	10.6	.4	31.9	115.0	145.7	2.5	438.9
Total	129.3	250.4	175.0	622.0	182.2	189.5	79.9	748.1
Usable forage [2]	38.0	141.2	109.7	372.7	49.1	39.5	44.8	223.6

[1] Less than 0.1 pound.
[2] Calculated from utilization records.

INFLUENCE OF GRAZING INTENSITY ON SHEEP PRODUCTION

Concurrently with the studies of herbage yields and vegetal changes, data on sheep production were maintained. Records of body weight were made for all ewes assigned to the experimental range pastures. Additional data on body weights of ewes together with information on wool yields, death losses, lamb crops, and income were obtained for the two herds (designated as A and B) that grazed in alternate years on the experimental range allotments and on nearby unfenced range. Further records included observations on supplemental feeding of both these herds as well as others grazing in the vicinity of the experimental range.

Sheep Production on Range Pastures

Changes in body weight of ewes kept in the 20 experimental range pastures were recorded during each grazing season from the winter of 1937–38 to 1943–44. The sheep were weighed at the beginning of each grazing period—early, middle, and late winter—and at the end of the winter grazing season. The number of ewes assigned to each range pasture was varied each year in order to achieve the desired intensity of grazing on the basis of the expected herbage production estimated in October.

The sheep were allowed to graze freely without herding. They had access to snow or water every day. When snow was not readily available, water was trucked to the ranges and placed in troughs. The sheep were bedded in different locations from time to time and the troughs were moved frequently to aid in obtaining uniform utilization within the range pastures. During cold weather it often was necessary to break and remove ice from the troughs so the sheep could drink.

Average changes in body weight of ewes that were kept throughout the winter season on the range pastures are shown in figure 19 for the 6-year period during which records were maintained. Ewes kept throughout the winter on lightly or moderately grazed range showed a net gain in each of the three winter grazing periods. The gains under moderate grazing in the first two periods exceeded those made on lightly grazed range. In the late winter period, ewes under light grazing gained slightly more than those under moderate. Total net gain for ewes under moderate grazing (11.4 pounds) was well above that for ewes under light grazing (8.5 pounds). Ewes in the heavily grazed pastures lost weight during the early and midwinter periods but gained about 2 pounds per head in the late winter period when early green growth of the forage plants became available. The gain during the late winter period under heavy grazing was less than half the gains made under light and moderate grazing, and was insufficient to offset earlier losses.

The weights reported do not completely measure actual flesh condition of the animals. Ewes weighed at the end of the winter grazing season bear between 4 and 5 pounds more wool than at the beginning. Many of those a year or more old are carrying lambs which, together with fetal tissue and liquid, weigh 10 to 15 pounds by spring. Pregnant ewes that weigh the same in spring as they did when they reached winter ranges may therefore have lost 15 or 20 pounds in flesh when deductions are made for current wool growth and unborn lambs. Much wider variations in weight occurred in the late winter period than in the other two. This was probably because of differences in weight of fertile and barren ewes and differing stages of pregnancy of the fertile ewes.

The kind and amount of forage produced on range areas influenced sheep weights considerably. Ewes in the lightly grazed range pastures 10 and 11, where vegetation is primarily sand dropseed and shadscale with very small amounts of winterfat, showed approximately 2 to 3 pounds less gain than those in other moderately or lightly grazed pastures. Sheep made the greatest gains on areas where winterfat, Indian ricegrass, and bud sagebrush produced 30 percent or more of the forage.

Weight changes throughout the winter grazing season were also influenced by the condition of the sheep when they reached the winter range. In years when summer and fall forage was inadequate and dry, many sheep arrived on the winter range in rather poor condition. These animals usually failed to improve much even on moderately grazed range.

To determine the interrelated effects of grazing intensity on sheep condition from one winter period to another, a special study was made in 1940–41 and 1941–42. Fifty-four ewes of two age classes—27 three-year-olds and 27 four-year-olds—were carefully selected for uniformity of size and condition, at the beginning of the winter grazing season. These sheep were randomly assigned to 9 range pastures in such a way that one sheep from each age class was subjected to each of the 27 possible grazing treatments involving the 3 winter grazing periods and 3 grazing intensities.

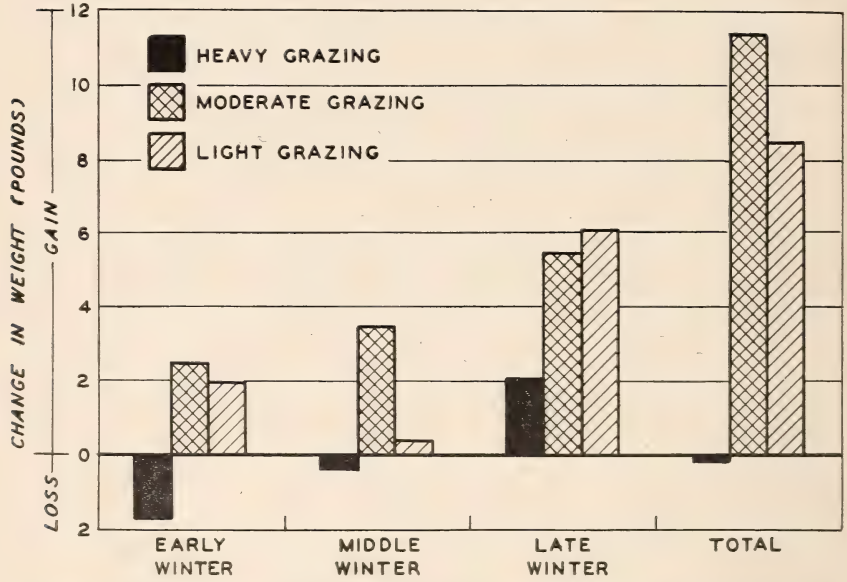


FIGURE 19.—Average changes in body weight of ewes that grazed experimental range pastures throughout each grazing season at light, moderate, and heavy intensities. 1938–39 to 1943–44, inclusive.

These treatments are shown in figure 20. For example, 7 pairs were in lightly grazed pastures two or more periods, of which pair No. 1 was in lightly grazed pastures during all three winter periods; pair No. 2 was in lightly grazed pastures in the early and middle periods and in moderately grazed pastures in the late winter; and pair No. 7 was in heavily grazed pastures in the early period and in the lightly grazed pastures in the other two periods.

Averaged data for the light grazing treatment show that ewes gained a total of 8.4 pounds per head — 3.2, 1.4, and 3.8 pounds per head respectively for the early, middle, and late winter periods (fig. 20). The average total gain for moderate grazing was 13.0 pounds per head.

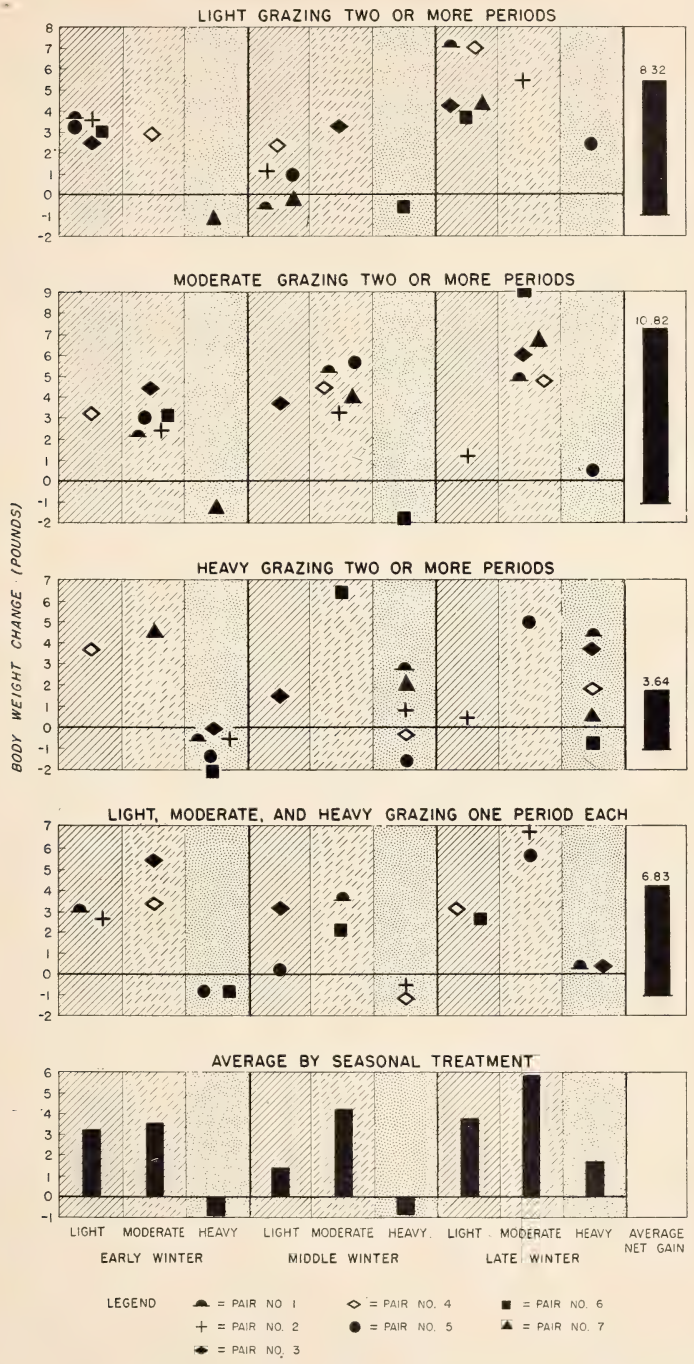


FIGURE 20.—Average changes in body weight of two ewes each season in range pastures for all grazing periods and intensities, 1940–41 and 1941–42.

In contrast, sheep in heavily grazed pasture failed to gain. These results are quite similar to those already reported for other sheep in the pastures. Ewes that were on moderately or lightly grazed range for two or more of the winter periods gained two to three times as much as those on heavily grazed range for two or more periods. Sheep that remained vigorous and in good condition through one period of heavy grazing frequently gained rapidly the following period if they were placed on moderately or lightly grazed range. An example of this is pair No. 6 of the set that were on moderately grazed range for two or more periods. The pair was on moderately grazed pasture in early winter, on heavily grazed pasture in the middle winter period, and on moderately grazed pasture again in late winter. Although the pair lost an average of nearly 2 pounds during the middle period, it made an average gain of 9 pounds during the late period.

Sheep under moderate grazing often gained more than those in the lightly grazed range pastures. This may be partly because herbage production and plant composition in the various pastures differed, and partly because the sheep in smaller groups using the lightly grazed areas were more restless and discontented than the larger groups of sheep in other range pastures.

Sheep Production on Range Allotments

To compare differences in production between sheep on moderately and heavily grazed winter range, two large experimental allotments were selected and two full-sized winter herds of 2,500 to 3,000 sheep, essentially similar with respect to breeding history and range operations, were used.

In 1935 the two experimental allotments were typical of neighboring winter rangelands with respect to topography, vegetation, and range conditions. Both of the allotments or range areas extended from the valley bottoms to the mountains. For the most part, they had been heavily grazed in previous years and were classed as in poor condition. One of these was located on the Desert Experimental Range and the other was on a similar adjacent range.

The allotment within the experimental range was moderately stocked at an average rate of approximately 15 sheep-days per acre during the period of the study, 1935 to 1947. The rates varied from about 27 sheep-days per acre in the most productive winterfat and black sagebrush subtype to as low as 5 sheep-days per acre on the poorer sites in the shadscale subtypes. The rate of stocking also varied from year to year with herbage production.

Ordinarily the herd was placed on the moderately grazed experimental allotment in early November as soon as it reached the winter range and remained until late April. In years when forage yields were low the sheep did not enter the moderately grazed experimental allotment until late November or early December. The number of sheep-days feed available each year was approximated on the basis of the changes in herbage yields that were recorded in October in the range pastures, and the dates of entry were varied accordingly.

Utilization was fairly uniform from year to year. However, from the time the herd reached the winter range in early November until it entered the moderately grazed allotment, adequate forage was available on other parts of the general winter range. During 1935 and 1936

grazing was somewhat lighter than in succeeding years. Average utilization of the various forage species for the period of the study was practically the same as that reported in table 1. Although adjustments in stocking were made, apparently they were not adequate to fully compensate for the wide fluctuations in production. As a result, utilization of the forage species was greater in years of low herbage yields than in years when production was above average.

For the heavily grazed allotment exact records of stocking or grazing use are not available because during the first 4 years of comparison the allotment was used in common by several herds which grazed in migratory fashion over wide areas of winter range. Utilization during this period was extremely heavy, the palatable species receiving probably one-third greater use than those on the moderately grazed allotment. During the last 5 years the heavily grazed allotments were assigned to individual sheep operators. Although this brought about some reduction in grazing intensity, utilization of the palatable species was still fairly heavy. The average intensities of grazing for the entire period were estimated to be about one-fourth heavier than in the moderately grazed allotment.

In 1942 about half of the herd assigned to the heavily grazed range was sold, leaving about 1,500 sheep. Because the two herds were no longer comparable in size the detailed comparisons were discontinued although some general phases of the study were carried on for a few more years.

Sheep in both herds were range-bred Rambouillets of good quality and essentially similar. The herds belonged to two brothers and had been previously owned and operated jointly by their father. Operating methods for both herds, designated A and B, were closely similar. During the winter of 1935–36 herd A was placed on the moderately grazed allotment within the experimental range and herd B was assigned to the heavily grazed range. In succeeding winters the assignments were reversed annually.

This alternating arrangement in grazing was used to eliminate differences due to management, herd performance, and the cumulative effects of previous grazing treatment which might be peculiar to the individual herds.

Management practices for the two herds differed throughout the period of observation. In the moderately grazed experimental allotment they were as follows: (1) The allotment was divided into units which were grazed at predetermined periods; (2) sheep were bedded in a new location each night; (3) herding was carefully controlled to permit quiet grazing and to check unnecessary trailing; and (4) water was supplied every day or every second day when snow was not readily available.

On the unfenced range, sheep were managed according to practice customarily used on many of the winter ranges in the Intermountain region: (1) The entire range area was grazed repeatedly as a single unit; (2) sheep were bedded on established bedgrounds, often for several nights in succession and often after trailing as much as 3 miles to reach a particular site; (3) trailing and movement were seldom checked by the herders; and (4) animals were primarily dependent on snow or reservoir supplies for water, and sometimes had to be trailed as much as 4 miles to get water during dry periods in early or late winter.

BODY WEIGHTS

Body weights of sample groups of ewes from herds A and B were recorded over a period of 7 grazing seasons (table 12). Seventeen ewes in each of seven different age classes were selected at random from each of the herds. They were weighed at the beginning and at the end of each winter grazing season.

Although some variations in the sheep weights were recorded each fall, sheep in the two herds were fairly comparable in weight in every year except 1943–44. In that year the sheep in herd A, placed on the moderately grazed range, weighed only 110 pounds per head and were visibly poorer than those in herd B which weighed 121 pounds per head when they were placed on the heavily grazed range in the fall.

TABLE 12.—*Average seasonal changes in body weight of 119 ewes in two herds (A and B) wintered alternately at moderate and heavy grazing intensities, 1937–44*

Grazing season	Moderate grazing			Heavy grazing		
	Fall weight	Spring weight	Change in weight	Fall weight	Spring weight	Change in weight
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1937–38	[1] *118.5*	*122.6*	*4.1*	116.4	111.8	−4.6
1938–39	114.7	122.3	7.6	*113.7*	*108.1*	*−5.6*
1939–40	*108.3*	*121.0*	*12.7*	111.9	119.6	7.7
1940–41	112.1	124.9	12.8	*110.1*	*113.3*	*3.2*
1941–42	*111.7*	*129.8*	*18.1*	113.0	124.2	11.2
1942–43	120.2	125.6	5.4	*118.0*	*112.7*	*−5.3*
1943–44	*109.6*	*114.0*	*4.4*	121.1	122.5	1.4
Average	113.6	122.9	9.3	114.9	116.0	1.1

[1] Figures in italic type for herd A, others for herd B.

Sheep on the moderately grazed range under good management showed an average seasonal gain of 9.3 pounds per head for the entire period of study, whereas those on heavily grazed range with poor management gained only 1.1 pounds per head. The 8.2 pounds difference between the two herds was nearly the same as that recorded for the sheep in the moderately and the heavily grazed pastures where the treatment and management were uniform. There were great fluctuations in weight changes from year to year, primarily because of differences in forage production and weather conditions. Notwithstanding this fact, the sheep on moderately grazed range remained in good condition and showed gains in all winters (fig. 21). Ewes on moderately grazed range made greater gains in every year than those on the heavily grazed range. In three winters—1937–38, 1938–39, and 1942–43—when weather conditions were rather severe, sheep on heavily grazed range showed net losses in weight.

In the concluding year of this phase of the study, half of herd B, which was then on heavily grazed range, was sold. Although the remaining sheep had ample forage throughout the winter, much of it was

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FIGURE 21.—Sheep grazing black sagebrush in an experimental allotment during the early winter. The tall, nutritious forage plants in this allotment enabled ewes to maintain themselves in good condition throughout most winters.

of low quality. As a result the sheep gained an average of 3 pounds less than those on the moderately grazed range. Differences in condition of the sheep in the two herds, when they reached winter range in the fall, may also have influenced the weight gains.

Average weight changes in sheep by age class for the period of study are shown in table 13. Sheep in each of the age classes were fairly comparable as indicated by fall weights. The most actively growing class, those under 1 year, naturally made the greatest gains in weight. Gains for this class under moderate grazing, however, were twice as great as under heavy grazing. Breeding ewes (those 1 year old or older) on moderately grazed range gained approximately 9 pounds per head, whereas those on heavily grazed range made a gain of only 0.4 pound or one-twentieth as much. Under heavy grazing ewes 6 years old or older showed a net loss of 0.5 pound in body weight. In severe winters the greatest loss occurs in ewes over 6 years of age and in the young sheep less than 1 year old. The old ewes on heavily grazed range lose weight rapidly, especially in cold weather, and become poor and weak.

Trends of weight changes of the sample ewes in herds A and B during the grazing seasons of 1937–38 and 1938–39 are shown in figure 22. In these years weights were recorded at several intervals throughout the winter. Weather in the winter of 1937–38 was rather severe and grazing was difficult for both herds. During part of the winter of 1938–39 weather conditions were likewise severe. In spite of this the sheep remained in good condition because they had access to the excellent forage crop that was produced the previous summer. In both years, however, ewes on moderately grazed range showed net gains in weight at the end of the season, whereas those on heavily grazed range lost weight rapidly during the midwinter period and failed to gain enough in the late winter to offset the loss.

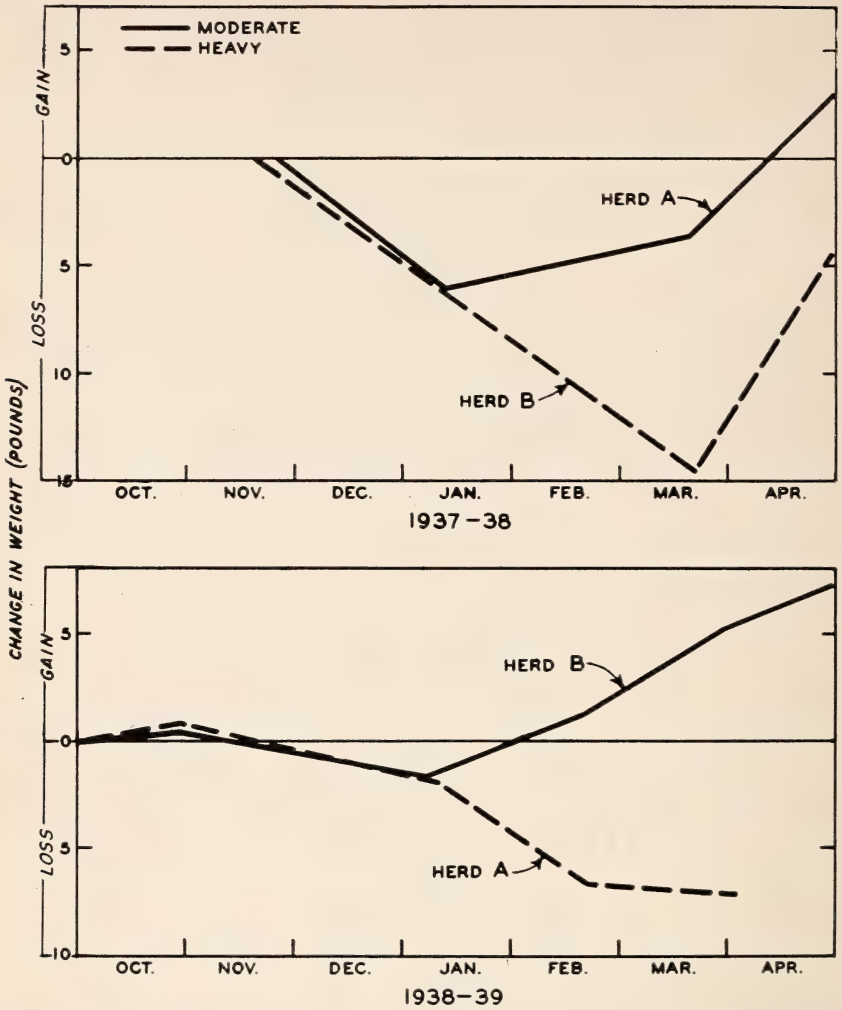

FIGURE 22.—Changes in weight of 119 ewes in herds A and B, which were wintered alternately on moderately and heavily grazed ranges for the grazing seasons of 1937–38 and 1938–39.

During the first part of the winter period both herds showed about equal weight trends. Apparently there was sufficient forage for the flock on the heavily grazed range until sometime in January. Then the two herds began to show differences in body weight. Since the ewes were bred during December, fetal development undoubtedly influenced the body weight of ewes throughout the winter. During the midwinter period ewes on moderately grazed range gained in body weight. In contrast, the ewes on heavily grazed range continued to lose weight until sometime in March. The differences in body weight on the moderately and the heavily grazed range were similar in most years of the study.

TABLE 13.—*Average fall and spring weights and change in body weight by age classes of 119 ewes in two herds (A and B) wintered alternately at moderate and heavy grazing intensities, 1937–44*

Age class	Moderate grazing			Heavy grazing		
	Fall weight	Spring weight	Change in weight	Fall weight	Spring weight	Change in weight
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Under 1 year	72.3	83.4	11.1	73.0	78.1	5.1
1-year-olds	105.6	114.4	8.8	111.8	113.1	1.3
2-year-olds	118.3	128.2	9.9	118.4	118.6	0.2
3-year-olds	120.9	130.8	9.9	123.8	124.5	.7
4-year-olds	127.6	135.8	8.2	125.9	126.8	.9
5-year-olds	126.1	135.3	9.2	126.3	126.4	.1
6-year-olds and over	124.2	132.3	8.1	125.0	124.5	−.5

During the unfavorable winters of 1937–38 and 1942–43, ewes on heavily grazed range suffered losses of as much as 20 to 25 pounds in body weight. These drastic losses often left the animals so weak that many were unable to survive the long trailing and trucking necessary to return them to the spring shearing and lambing ranges.

WOOL YIELDS

Fleece weights of all sheep that wintered on the experimental allotments were obtained after spring shearing from 1936 to 1943. The averages for herds under the two treatments are shown in table 14. Weights given are on the "grease" or "dirt" basis before the fleeces were washed.

Average fleece weights were greater in every year for the herds that grazed at a moderate level. The difference varied from a low of 0.24 pound per head after the winter of 1935–36 to a high of 1.67 pounds after the winter of 1936–37, and averaged 0.95 pound for the period of observation.

The greater fleece weight of the sheep on the moderately grazed areas is attributable to the larger amounts of nutritious forage they consumed. A previous study in New Mexico has presented evidence that the plane of nutrition has a marked influence on wool yields, and that well-fed sheep produce more wool than underfed ones (*22*).

DEATH LOSSES

Observations on winter death losses were made on herds A and B during the period of study. Death losses among the sheep on the moderately grazed range averaged 3.1 percent, of which about 2 percent were killed by coyotes and the remainder died from unknown causes. Death losses of sheep on heavily grazed range were more than double with an average of 8.1 percent, of which a little more than half was due to causes incident to malnutrition and the rest to coyotes and

unknown causes. Occasionally after winters of very short feed, especially when weather was cold and the snow deep, sheep on the heavily grazed range became very weak by spring and losses were extremely high. In 1932, after a severe winter, losses of 10 to 20 percent were common on heavily grazed ranges in the general vicinity of the Desert Experimental Range; some herds suffered losses as high as 50 percent.

TABLE 14.—*Average fleece weights from two bands of sheep, one on moderately grazed range and one on heavily grazed range 1935–36 to 1942–43* [1]

Grazing season	Moderate grazing	Heavy grazing	Difference
	Pounds	*Pounds*	*Pounds*
1935–36	[2] *11.15*	10.91	0.24
1936–37	10.79	*9.12*	1.67
1937–38	*10.70*	10.16	.54
1938–39	10.94	*9.28*	1.66
1939–40	*10.51*	9.33	1.18
1940–41	[3] 9.58	*9.53*	.05
1941–42	*10.67*	9.02	1.65
1942–43	10.67	*10.10*	.57
Average	10.63	9.68	.95

[1] All weights on "grease" basis; averages from 1939–40 onward adjusted to uniform shrink (approximately 61 percent).

[2] Figures in italic type for herd A, others for herd B.

[3] Losses of approximately 1 pound per head in sagebrush range prior to shearing not included.

LAMB CROPS

Lamb crops of herds wintered in the moderately grazed allotments and on heavily grazed range were recorded between 1935 and 1946. Counts of lambs were made at docking time. Data from these counts are shown below in terms of the number of lambs docked per hundred ewes.

Grazing season:	*Lambs produced per 100 ewes*	
	Moderate grazing (number)	*Heavy grazing (number)*
1935–36	75	70
1936–37	76	69
1937–38	73	74
1938–39	86	65
1939–40	87	92
1940–41	106	78
1941–42	92	84
1942–43	94	87
1943–44	73	85
1944–45	104	67
1945–46	98	93
Average	88	79

Ewes that wintered on moderately grazed range usually produced more lambs the following spring than those that wintered on heavily grazed range. Following the winter grazing seasons of 1937–38, 1939–40, and 1943–44 more lambs were docked from the herd which wintered on heavily grazed range. In spite of this disadvantage the herd on moderately grazed winter range produced, on the average, 11 percent more lambs than the herd that wintered on heavily grazed range. Lambs at market time were also slightly heavier.

SUPPLEMENTAL FEEDING

Practices in regard to the feeding of supplements vary somewhat on the winter range. A few herds are fed supplements throughout each winter. Most herds, however, are fed for a short time only in the late winters when forage is unusually scarce and the condition of sheep is noticeably poor. Occasionally entire herds are fed in this manner, but in most cases only the poorer sheep are given supplements in separate bands.

As a rule such feeding begins about January 15 and continues through March or April or until green forage becomes available. Sheep are usually fed ⅛ to 1 pound per day of cottonseed cake, grain pellets, or corn.

During the period of study, sheep within the moderately grazed experimental allotment wintered in good condition even in severe winters without any supplemental feed. Sheep on the heavily grazed range were fed some supplements for short periods during a few of the severe winters. The usual practice was to feed only the poorer sheep. Although they received this supplemental feed, many of the animals still lost weight and death losses were heavy. Several other herds on adjacent heavily grazed range were fed considerable amounts of cottonseed cake or corn during 3, 4, or 5 years to help carry the sheep through periods when range forage was inadequate. In the fairly severe winter of 1936–37, these herds were fed cottonseed cake during a period of 4 to 6 weeks. Nevertheless, many of the ewes remained in poor condition and death losses were high.

Studies in recent years have shown that many of the winter range forage plants are low in nutritional and mineral content (*3*, *5*, *6*). It is therefore probably desirable to feed supplements in most years to supply dietary deficiencies even for sheep on moderately grazed areas. Some experiments to determine what supplements may be necessary are being conducted at the Desert Experimental Range in cooperation with the Utah State Agricultural College. These studies show that most of the forage plants are deficient in phosphorus and that condition of sheep is markedly improved when they are fed supplements containing this element.

INCOME

Financial and operational data were obtained for herds A and B covering 8 years. These data were combined for each type of grazing treatment. Since the herd sizes varied, figures were recomputed on the basis of 3,000 head to make them directly comparable (table 15).

TABLE 15.—*Average production and income of herds on moderately and heavily grazed range, 1935–43* [1]

Item	Moderately grazed range	Heavily grazed range
Ewes sold—number	297	207
Income from ewes	$891.00	$621.00
Breeding ewes—number	2,610	2,550
Lamb crop—do	2,297	2,015
Lambs held—do	390	450
Lambs sold—do	1,907	1,565
Weight of lambs sold—pounds	143,025	109,550
Sale price per pound	$0.085	$0.08
Income from lambs	$12,157.13	$8,764.00
Ewes sheared—number	2,953	2,878
Fleece weight—pounds	10	9
Wool produced—do	29,530	25,902
Income from wool [2]	$10,335.50	$9,065.70
Income from pelts	$46.50	$121.50
Gross income	$23,430.13	$18,572.20
Costs [3]	$13,050.00	$13,500.00
Net income	$10,380.13	$5,072.20

[1] Data for herds A and B, which grazed alternately on the two areas, combined by treatment and recomputed on the basis of 3,000 head.

[2] Sale price of wool $0.35 per pound.

[3] All operating costs, including taxes, replacements, labor, feed, and miscellaneous.

Costs of operations and prices received are those that prevailed during the period of the study. Wool sales were not uniform for the two herds. In some years the wool was sold; in other years one or more of the operators shipped it on consignment to Boston. To eliminate the difference in sale method and prices obtained for wool, $0.35 per pound was used to compute the income for wool for the two flocks. This is approximately the average sale price of wool prevailing during the study. Higher prices and operational costs now prevailing would no doubt affect the total income. However, the comparisons between moderate and heavy grazing would be proportionate to the values given.

Average net return from the herds on moderately grazed range was slightly more than twice as great as that from the herds on heavily grazed range. Annual net income per head from moderate grazing was $3.46 as compared with $1.69 per head for heavy grazing.

The greater net return on the moderately grazed range areas was directly attributable to the generally better conditions of the sheep there. Death losses were lower, fewer lambs were needed for replacement, and a greater number could be sold. The herds on moderately grazed range also had a larger number of breeding ewes. Because of these interrelated factors these herds produced for market 31 percent more lamb, 43 percent more mutton, and 14 percent more wool. In addition lambs, being approximately 5 pounds heavier, sold on the average for one-half cent more per pound.

Costs of operation during the period of study were greater in all years for the herds that grazed at heavy intensity. This was primarily because of increased expenditures for ewes in poor condition, including trucking and feeding costs. The greater replacement costs after heavier

death losses formed another item of expense which reduced the net income from the herds on heavily grazed range.

These studies show that production of both sheep and forage are improved under moderate grazing and good management. They also show that income is greatly reduced by heavy stocking. This is also borne out by results of an economic study of sheep enterprises in southwestern Utah (*2*), where it was found that income per ewe was not associated with size of enterprise or number of sheep owned but rather with lamb and wool yields. Although management practices and intensities of grazing use were not evaluated in that study, they undoubtedly had considerable influence on lamb and wool production. A study of 8 ranches in New Mexico (*14*) has also shown that the greatest production of wool and lambs was obtained where moderate grazing levels were maintained in conjunction with good management practices.

GUIDES FOR INCREASING FORAGE AND SHEEP PRODUCTION

The investigations at the Desert Experimental Range have shown that forage production on ranges in depleted condition can be increased under moderate grazing use by sheep. Such use must be in balance with the potentialities of various range areas to produce forage. To assess this potentiality requires knowledge of the composition of the vegetation and present condition of the range. With this basic knowledge, a program for the improvement of forage and the maintenance of sustained high levels of sheep production can be undertaken.

In the following sections some suggestions are given for analyzing winter range condition and instituting proper utilization standards, stocking rates, and management practices. These are the tools by means of which the objectives of increased forage yields and improved sheep production can be reached.

Judging Range Condition

The term "condition" is used to denote the general health and productivity of the range. From extensive observations on winter ranges throughout the region, and information obtained on specific sites within the Desert Experimental Range, criteria or indicators were developed to aid in judging the state of health or condition of the range. Among the more important of these on winter ranges are: The status of soil, composition of vegetation, vigor of plants, and the kind and amount of seedlings and young plants.

Using these indicators it is possible to judge and classify the present condition of most winter range areas. The following condition classes illustrate how the various indicators are related to range condition.

1. *Good condition*—Soil stable with little or no evidence of accelerated erosion; plants not pedestaled, good stand of palatable vegetation in vigorous condition with production approaching a maximum consistent with precipitation; seedlings of palatable species abundant enough to maintain the current composition of the vegetation.

2. *Fair condition*—Soil showing signs of accelerated wind and water erosion; undesirable species of low palatability present on some areas and predominant on others; introduced annuals such as Russian-thistle,

halogeton, or cheatgrass scattered throughout the vegetation or on a few localized spots; plant cover broken, and a number of dead and partially dead plants of the palatable species such as Indian ricegrass, winterfat, black sagebrush, and bud sagebrush present.

3. *Poor condition*—Soil erosion active; palatable native species often pedestaled; plant cover thinned, numerous dead or partially dead plants of palatable species, numerous introduced annuals such as Russian-thistle, halogeton, mustards, cheatgrass, and foxtail bromes; species of low palatability producing about 50 percent of the herbage.

4. *Very poor condition*—Soil erosion active; many of the smaller drainages raw and eroding with very little vegetation; numerous annuals and species of low palatability producing most of the current herbage; most of the palatable native vegetation severely injured or destroyed.

On the basis of extensive surveys made on the winter ranges of the Intermountain region from 1932 to 1936, and observations made on numerous enclosures scattered throughout Utah and Nevada, the majority of these areas were classified as being in fair to poor condition, with a considerable amount of range in very poor condition. Although some of these areas have shown improvement during the last few years under management, many of the ranges are still in fair to poor condition, producing far below their maximum capacity.

The rate of recovery of the range varies according to subtype and range condition. Some subtypes within the Desert Experimental Range, which were classified in poor condition in 1935, improved enough under moderate grazing to be classed as in good condition in 1947. Subtypes in which palatable perennial forage plants were present in moderate numbers, even though low in vigor, recovered rapidly. In 3 to 5 years, improvement in vigor of the better forage species was readily apparent. Many young plants and seedlings of the choice forage species were also present.

Recovery of areas in poor condition where palatable plants have been severely injured or replaced by undesirable species is much slower, but improvement is generally feasible if moderate grazing and carefully planned management practices are adopted. The improvement of ranges in very poor condition requires more than the reduction of grazing intensities. It may be advisable to suspend grazing for varying periods of time, depending on the degree of deterioration that exists. If reseeding of such areas can be done successfully, it will undoubtedly speed recovery. Very little, however, is yet known about methods and species suitable for seeding on these semiarid rangelands. Much further research will be necessary before seeding of winter ranges can be relied on to bring about widespread improvement.

Utilization Standards

Utilization records of winter grazing at the Desert Experimental Range indicate that Indian ricegrass, black sagebrush, and winterfat, all important key forage species, can remain productive and vigorous on ranges in fair to good condition when 75, 60, and 55 percent, respectively, of their current herbage is utilized. Under this moderate degree of utilization 25, 40, and 45 percent, respectively, of the herbage is left ungrazed as protection to the plants and to insure sustained production of the seed and of other important forage species.

The following minimum stubble heights and twig lengths are characteristic of moderately grazed winter range. Indian ricegrass will have an average of 2 to 3 inches of stubble remaining at the end of the grazing season. Although all plants are usually grazed, a few of the larger, more robust ones will usually have as much as 5 or 6 inches of stubble. On galleta an average stubble height of 1 to 1½ inches will remain and 5 to 10 percent of its ground area, usually toward the perimeter of stands, will be ungrazed. Black sagebrush will have an average of 1½ to 2½ inches of current twig growth remaining and in years when seed stalks are produced in abundance, 10 to 20 percent of these will be ungrazed. On winterfat 1½ to 2½ inches of current growth will remain and 10 to 15 percent of the plants will appear to be ungrazed.

The percentages of utilization given in table 1 are useful utilization guides in subtypes where the species listed make up a large part of the plant cover or herbage production. These utilization guides should be adhered to rather closely in order to maintain a moderate grazing intensity. On range subtypes where winterfat, bud sagebrush, black sagebrush, Indian ricegrass, and galleta do not occur, or on ranges where they make up only a small proportion of the vegetation, it may be necessary to select other key forage species on which to base utilization guides. If scattered but choice forage species are to be maintained in the plant cover, it may be necessary to use some of these as key species and to reduce the grazing level enough to prevent grazing injury.

Where ranges are in a deteriorated condition, utilization percentages must be adjusted to provide for range recovery. On ranges in poor condition it may be necessary to leave more than 50 percent of the herbage of the palatable species during 2 or 3 years while the vigor of the plants is being restored. This will allow them to compete more successfully with invading species or species of low palatability such as Russian-thistle, shadscale, or small rabbitbrush. On ranges in very poor condition it may be desirable to suspend grazing for as long as 2 years or to allow grazing only every other year. Within the experimental range, a severely depleted winterfat subtype made satisfactory improvement when grazed moderately in alternate years.

Stocking Rates

Stocking rates for winter ranges should be in balance with the capacity of grazing areas to produce forage. This is necessary for efficient production of sheep. To adjust stocking rates annually to meet the wide fluctuations in forage production due to variations in precipitation is obviously impracticable, because flocks are primarily composed of breeding ewes which are grazed on other seasonal ranges to round out the yearlong range livestock operation. A more workable procedure is to adjust the numbers of sheep so that they will be in balance with the forage yield over a fairly long period of time. The term "forage" is used to denote the amount of herbage which can be grazed or used by sheep under moderate grazing without injuring the range or impairing future production. The average stocking rate should take into account differences in productive capacity of different plant subtypes on the grazing area. Provision should also be made for recurrent drought periods.

To provide for reasonable stability in winter grazing and to assure an adequate forage supply year after year, a basic stocking rate established at 75 percent of average forage production is recommended. This is approximately the level of stocking maintained at the Desert Experimental Range (fig. 23). On this basis, enough forage is provided for sheep in most years without need for further adjustment in numbers or supplemental feeding. Only in years of drought or low forage production would it be necessary to reduce sheep numbers or to provide supplemental feed.

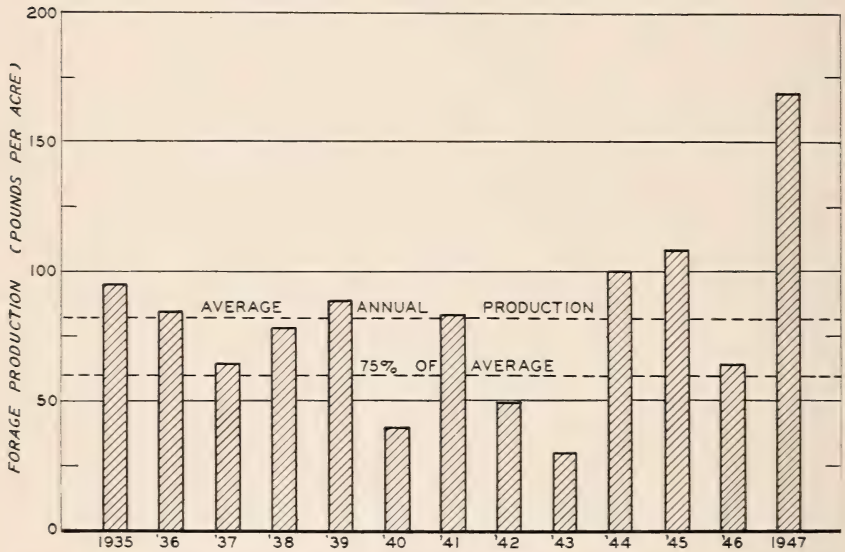

FIGURE 23.—Forage production of moderately grazed range areas at the Desert Experimental Range, 1935–47. Utilization of the forage at 75 percent of the average provided a margin of safety in all but 3 years when production was extremely low.

Forage forecasts based on the previous 12-month rainfall make it possible for stockmen to foresee grazing seasons of short forage. It is then possible to provide additional feed or arrange for the adjustment of numbers before taking the sheep to winter ranges.

In establishing stocking rates the plant composition of the grazing area and its present condition should be considered. Average grazing capacities of seven subtypes in two condition classes, expressed in acres required per sheep-month, are as follows:

Subtype:	*Fair to good condition (acres)*	*Poor condition (acres)*
Shadscale-grass	3.5	5.7
Shadscale-winterfat-grass	2.3	3.7
Black sagebrush-shadscale-grass	1.0	2.3
Winterfat-small rabbitbrush-grass	1.2	2.8
Littleleaf mountain-mahogany-black sagebrush-grass	2.8	4.3
Winterfat	1.0	2.4
Gray summer-cypress-Gardner saltbush-winterfat	1.9	2.6

These capacities were calculated by multiplying the air-dry herbage yields obtained on the range areas in different conditions by the average percentage utilization recorded on the moderately grazed experimental range. The result was divided by 5.5 pounds, which is the approximate range forage requirement including trampled herbage for a ewe per day.

There is considerable variation in grazing capacity according to the composition of a subtype and its condition. Subtypes where winterfat and black sagebrush are abundant have the highest capacities and those where shadscale is predominant, the lowest.

Subtypes in poor condition have a thinner cover of plants, usually including few of the palatable species and a great many of the less palatable. Because such range areas produce much less forage, grazing capacity is only one-half to two-thirds that of comparable areas in fair to good condition.

Management Practices

After a program of moderate grazing has been installed on any winter range area, it is of paramount importance to apply the best management practices. The management practices outlined here will greatly aid in obtaining uniform distribution of sheep, effective utilization of forage, and efficient sheep production.

SUBDIVISION OF RANGE ALLOTMENTS

The subdivision of a large range allotment into smaller units that are grazed at specified winter periods, as practiced at the Desert Experimental Range, has several advantages over random grazing of the entire allotment. This is especially true when the periods of grazing on units are rotated from year to year.

A new supply of a mixture of forage is assured when sheep are removed from one unit and brought to a previously ungrazed one. Another advantage is that portions of an allotment can be reserved for use during shearing in portable corrals on the winter range.

General observations at the Desert Experimental Range indicate that several forage species made superior gains in volume on units grazed during the early and middle winter periods but not in the late winter. These species included bud sagebrush, Indian ricegrass, hopsage, and squirreltail. All begin their growth in the early spring, which coincides with the late winter grazing period, and grazing them at that time reduced their vigor considerably. To permit maximum production of these species it may be necessary to eliminate the late winter grazing on a portion of the allotments each year. This can be accomplished by rotating the use of three or more units so that some of the units are not grazed in the late winter period for one or two years in succession.

HERDING

The following herding practices are recommended on the basis of experience at the experimental range: (1) Allow sheep to spread out and graze quietly and keep trailing in groups to a minimum; (2) plan routes

of grazing to give sheep a variety of forage but at the same time avoid prolonged use of any particular area; (3) bed sheep in a different location each night, preferably one that is selected beforehand so that the animals can reach it after the day's grazing; and (4) avoid overuse of dogs, since they encourage close herding.

It may be necessary to corral herds at various times during the winter for such purposes as making counts, marking, shearing face wool, or segregating sheep. This can be done in portable corrals constructed of panels or lath snow fences and steel posts. Such corrals should be placed on hard or somewhat gravelly ground to avoid excessive damage from trampling.

Shearing in portable corrals before the sheep leave the winter ranges is becoming a common practice. One or two flocks are shorn at a corral location, usually near water. The sheep are removed from the shearing area immediately after they are shorn and placed on ranges where forage is available. The corral is then moved to a new location for the next herd. Adjacent range areas are used for grazing only briefly and therefore are not given as severe use as areas around permanent shearing corrals where several flocks are shorn year after year. It may be highly desirable to place the shearing corrals in a new location each year to prevent injury to the range.

WATERING

Adequate watering of sheep is important in keeping them in good condition. Studies at the Desert Experimental Range (*8*) indicate that sheep require about 0.7 gallon each per day on winter range. In warm weather they may need 1.5 gallons and if forage is dry or composed mostly of shadscale or Gardner saltbush as much as 2 gallons per day.

Sheep should receive a supply of fresh water every day. During the middle part of most winters they can obtain the necessary water from snow, provided it is uniform and not too deep. Relying entirely on snow for water throughout most winters, however, places undue hardships on the sheep and on the range. Even in the middle winter there may be too little snow, or snows may be crusted and hard to utilize for water. In early and late winter when snow is scarce, animals must be trailed back and forth from grazing areas to higher elevations for snow or to reservoirs where water is available.

A much better practice is to truck the water to the sheep, preferably every day when snow is not uniformly and readily available. Water may be supplied in portable troughs, which should be placed so that sheep movements can be directed across the desired range areas. Enough troughs should be provided to avoid crowding. A spacing of 40 to 50 feet between troughs is recommended.

SUMMARY

Winter ranges in the Intermountain region furnish forage for approximately 4 to 5 million sheep for a period of 4 to 6 months. These ranges are extensive, comprising in all about 65 million acres. They are characterized by low precipitation and scant vegetation. This naturally sparse plant cover has been greatly depleted by grazing over-

use from the turn of the century up to recent years. The depletion has been further intensified by accelerated wind and water erosion and by droughts. To bring about recovery and insure maintenance of these important ranges will require knowledge of their grazing potentials and application of improved management practices based on this knowledge.

The Desert Experimental Range was established by the Forest Service in 1933 for the study and solution of problems existing on such rangelands. Fifty-five thousand acres of typical winter range in western Millard County, Utah, were selected and fenced into experimental pastures and allotments. Studies were conducted on these areas and on neighboring open range from 1935 to 1947 to determine: (1) The utilization of forage species by sheep; (2) the influence of precipitation on herbage production; (3) the effects of grazing intensity on forage yields; and (4) the effects of grazing intensity on sheep production.

Detailed data on herbage production, plant density, and utilization of vegetation as well as weight changes of sheep were obtained from the experimental pastures, which were grazed at light, moderate, and heavy intensities. Additional data on herbage production, forage utilization, and several phases of sheep production were obtained from two range allotments, one heavily and one moderately grazed, on which two herds of sheep were alternately wintered.

The plant types and subtypes characteristic of the winter range are well represented within the experimental range. Seven major subtypes cover more than 94 percent of the area, with pinyon and juniper forming an open overstory on about one-fifth of the total. Several hundred plant species are found on both the experimental range and the general winter range but only about 30 are abundant and palatable enough to be classed as important forage species.

Within the experimental pastures, located on valley alluvial fans, vegetation consists chiefly of shadscale-winterfat-grass subtypes. These are among the most extensive plant subtypes on the winter range but they are not the most productive of forage. During the period of study, five species—winterfat, shadscale, Indian ricegrass, galleta, and sand dropseed—produced 80 percent of the herbage and furnished 88 percent of the forage in moderately grazed pastures. Winterfat alone contributed 35 percent of the forage, almost twice as much as any other plant.

Utilization of forage plants was influenced primarily by their level of palatability, but other factors such as relative abundance, stage of maturity, and weather conditions also had considerable influence on the kind of forage eaten. Winterfat, Indian ricegrass, sand dropseed, and galleta were utilized more heavily in pastures where they were relatively scarce than where they made up larger proportions of the herbage.

Total herbage production of the subtypes within the pasture area, as estimated in October, was closely associated with precipitation received during the preceding 12 months. Average 12-month precipitation between October 1934 and October 1947 was 6.69 inches. Average herbage production was only 219 pounds per acre with a maximum of 468 pounds in October 1947 following 11.10 inches of precipitation, and a minimum of 75 pounds in 1943 after 2 years of drought.

Herbage production was found to increase approximately 46 pounds an acre with each additional inch of precipitation. This close relation has provided a basis for forecasting forage at the experimental range from precipitation records up to October of each year. Such forecasts would enable sheep operators to provide supplemental feed or otherwise make adjustments for indicated short forage before taking their herds to the winter range.

In the pastures the trend of total herbage production during the period of study was upward under all three intensities of grazing, the increases being respectively 54, 46, and 34 percent for light, moderate, and heavy grazing. Winterfat, the most productive and palatable shrub in the pasture area, showed trend increases of 239, 321, and 33 percent under light, moderate, and heavy grazing. Shadscale, more abundant but lower in palatability, increased slightly more under moderate grazing and much more under light grazing than under heavy grazing. Galleta and sand dropseed declined slightly under all intensities of grazing primarily because of infrequent favorable summer rainfall. Indian ricegrass, bud sagebrush, and globemallow, which made up small amounts of the plant cover, did not show any consistent response to the differential grazing treatments.

Other plant subtypes showed changes in vegetal composition under two intensities of grazing on large range areas inside and outside of the experimental range. In a shadscale-Indian ricegrass subtype, yields of the palatable Indian ricegrass increased from 30 percent of the total in 1934 to more than 40 percent in 1947 under moderate grazing. Under heavy grazing production dropped to 15 percent of the total by 1947.

The valuable black sagebrush increased remarkably in volume under moderate grazing on a depleted subtype which originally produced primarily winterfat, rabbitbrush, and only small amounts of grass and black sagebrush. This species produced only 7 percent of the herbage in 1934 but by 1947 made up more than 40 percent of the total, because of increases in vigor and establishment and growth of seedlings. On the adjacent part of the subtype, where heavy grazing was continued, rabbitbrush remained the dominant species.

Low-value annuals and undesirable shrub species were generally supplanted by more palatable species when grazing pressure was reduced or suspended. As an example, an ungrazed enclosure was erected in 1937 on an area where Russian-thistle produced about 60 percent of the vegetation. Three years later this species was almost completely supplanted by winterfat and Indian ricegrass within the enclosure. By 1947 Russian-thistle produced only 2 percent of the herbage in the enclosure. On the neighboring heavily grazed range, Russian-thistle production was 402 pounds an acre or 54 percent of the total herbage.

Ewes on moderately grazed range maintained body weights of 4 to 18 pounds more than those on heavily grazed range. They also produced about a pound more wool and 11 percent more lambs. Costs of feeding sheep in poor condition and death losses were greatly reduced. Income from herds wintered at moderate grazing levels and under good management practices averaged $3.46 per ewe as compared to $1.69 from herds on heavily grazed range.

On the basis of findings at the experimental range, condition of winter range areas has been grouped into four broad classes which can be identified by relatively few indicators. These classes are: Good, fair, poor, and very poor. Knowledge of the extent of these condition classes on a range is essential to the application of proper utilization standards and stocking rates.

Records obtained at the experimental range indicate that approximately the following proportion of the herbage of major forage species can be eaten during the winter period without impairing their continued productivity: For Indian ricegrass 75 percent, black sagebrush 60 percent, winterfat 55 percent, and galleta about 45 percent.

To provide for reasonable stability in winter grazing and to assure an adequate forage supply in most years, a basic stocking rate that will utilize 75 percent of average forage production is recommended. Grazing capacities of range subtypes in fair to good condition are 1½ to 2½ times greater than for those in poor condition. On ranges in fair to good condition 1 to 3.5 acres are required per sheep per month, whereas on those in poor condition 2.3 to 5.7 acres are required.

Studies at the Desert Experimental Range indicate that certain management practices are of benefit to both ranges and sheep. These include subdivision of large grazing allotments so that grazing use may be rotated from year to year, use of open herding and one-night bedgrounds, leaving the range early to avoid grazing during the late winter period when many of the major forage plants begin to grow, and providing water for sheep each day.

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COMMON AND BOTANICAL NAMES OF SPECIES MENTIONED

Shrubs

Creosotebush, Coville	*Larrea tridentata*
Ephedra, Nevada	*Ephedra nevadensis*
Greasewood, black	*Sarcobatus vermiculatus*
Hopsage, spiny	*Grayia spinosa*
Horsebrush, littleleaf	*Tetradymia glabrata*
Mesquite	*Prosopis* spp.
Mountain-mahogany, littleleaf	*Cercocarpus intricatus*
Pickleweed	*Allenrolfea occidentalis*
Rabbitbrush, rubber	*Chrysothamnus nauseosus*

Shrubs—Continued

Rabbitbrush, small	*Chrysothamnus stenophyllus*
Sagebrush, big	*Artemisia tridentata*
Sagebrush, black	*A. nova*
Sagebrush, bud	*A. spinescens*
Sagebrush, fringed	*A. frigida*
Saltbush, fourwing	*Atriplex canescens*
Saltbush, Gardner	*A. gardneri*
Saltbush, mat	*A. corrugata*
Saltbush, shadscale	*A. confertifolia*
Seepweed	*Suaeda* spp.
Snakeweed, broom	*Gutierrezia sarothrae*
Summer-cypress, gray	*Kochia vestita*
Winterfat, common (whitesage)	*Eurotia lanata*
Yucca	*Yucca* spp.

Grasses and Grasslike Plants

Brome, cheatgrass	*Bromus tectorum*
Brome, foxtail	*B. rubens*
Dropseed, sand	*Sporobolus cryptandrus*
Dropseed, spike	*S. contractus*
Galleta	*Hilaria jamesii*
Grama, blue	*Bouteloua gracilis*
Needle-and-thread	*Stipa comata*
Needlegrass, Mormon	*S. arida*
Ricegrass, Indian	*Oryzopsis hymenoides*
Sacaton, alkali	*Sporobolus airoides*
Saltgrass	*Distichlis* spp.
Squirreltail, bottlebrush	*Sitanion hystrix*
Wheatgrass, bearded bluebunch	*Agropyron spicatum*
Wildrye, Salina	*Elymus salina*

Forbs

Globemallow, gooseberryleaf	*Sphaeralcea grossulariaefolia*
Halogeton	*Halogeton glomeratus*
Pepperweed	*Lepidium scopulorum*
Russian-thistle, tumbling	*Salsola kali tenuifolia*

Trees

Juniper, Utah	*Juniperus osteosperma*
Pinyon, singleleaf	*Pinus monophylla*

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